THE EARTH
AND THE
SOLAR SYSTEM

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THE EARTH

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The Earth and the Solar System.

LATITUDE AND LONGITUDE.

(For general description of the Earth, see *Moffatt's Physical Geography of Mountains and Rivers.*)

A Great Circle of a globe or sphere is one which passes round the globe or sphere and divides its surface into two equal parts.

The **Plane of a Circle** is an imaginary flat surface which fills up the circle, joining every part of the circumference with the centre.

The plane of a great circle passes through the centre of the globe or sphere.

A **Small Circle** is one whose plane does not pass through the centre of the globe or sphere. A small circle divides the surface of the sphere into two unequal portions.

Imaginary lines are supposed to be drawn on the surface of the earth. By reference to them the position of any point may be indicated.

The **Equator** is a great circle of the earth exactly mid-way between the North and South Pole.

Meridians are great circles of the earth supposed to be drawn through each pole and crossing the equator at right angles in two points.

By means of two great circles, the equator, and a meridian, the position of any point on the earth's surface may be described.

We could not denote the position of a point with reference to one line. Thus, take the line A B.

If we say that a certain fixed point is 3 inches from that line, the question arises ; *on which side* of the line does the point lie? This might be overcome by stating that the point is either above or below the line ; but then a further difficulty is met with, for the point might be at the distance of 3 inches from *any part* of the line A B. If the latter were of unlimited length then there would be an infinite number of positions in which the point might be placed.

Now draw a second line C D, cutting A B at right angles. By means of the two lines we can describe the position of the point exactly. For if we say that the point is 3 inches above A B and 2 inches to the right of C D, we shall find that only one point will fulfil these new conditions, and therefore the position of the required point will be found by carefully making the necessary measurements.

This is the principle on which the position of any point on the surface of the earth is indicated. The equator corresponds with the line A B, and a meridian with the line C D.

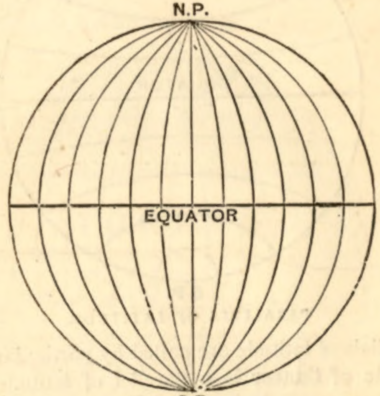
MERIDIANS (Lat. *meridies*, mid-day) are so called because when any one of them is, by the motion of the earth (and the apparent motion of the sun) brought directly opposite to the sun, it is always mid-day or noon to every place on that meridian. The sun is at his highest point in the sky at any place when he crosses the meridian.

The meridians are indefinite in number. Every point on the earth's surface has its own meridian, because a great circle may be drawn through any point through the poles, and at right angles to the equator.

By the meridian of a place is sometimes understood only the half of the great circle passing through the place ; the other half is then called the opposite meridian.

Distances on circles are measured, not by miles, yards, and feet, but by **degrees**. Every circle is supposed to be divided into 360 degrees ; each degree into 60 minutes ; each minute into 60 seconds, and so on. Abbreviations or signs are generally used ; thus $32^\circ\ 4'\ 15''$ signifies, 32 degrees 4 minutes 15 seconds.

Degrees, minutes, and seconds are not fixed lengths, like yards, feet, inches, etc. ; they vary according to the size of the circle to which they refer. A degree may be only an inch long, or it may measure many miles in length.



MERIDIANS OF LONGITUDE.

Meridians are also called **Meridians of Longitude.**

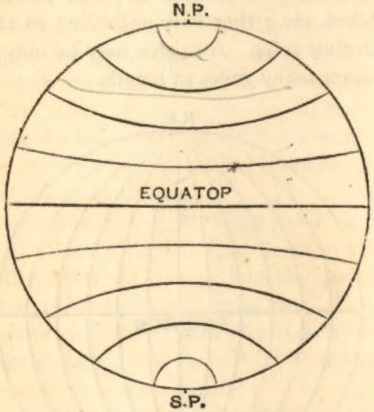
On globes and maps of the world, meridians are drawn through every ten or fifteen degrees. On maps representing

smaller parts of the earth's surface they are sometimes drawn through every degree. They are always drawn from the top to the bottom of a map.

PARALLELS OF LATITUDE are small circles drawn parallel to the equator.

These are also indefinite in number. They become smaller the further they are distant from the equator, either north or south. At the poles they contract to mere points.

It will be seen that a degree measured on a meridian is a fixed length (or nearly so),* since all the great circles are of the same size; but a degree measured on a parallel of latitude is a variable quantity.



PARALLELS OF LATITUDE.

Four parallels of latitude are called by particular names.

The **Tropic of Cancer** is a parallel of latitude 23½ degrees north of the equator. It marks the extreme distance north of the equator at which the sun, in his apparent annual path, is vertical at noon. (See Seasons, Page 29.)

* Degrees measured on meridians are not precisely of the same length, owing to the earth not being exactly a sphere, but an oblate spheroid.

The **Tropic of Capricorn** is a parallel of latitude 23½ degrees south of the equator. It marks the extreme distance south of the equator at which the sun, in his apparent annual path, is vertical at noon.

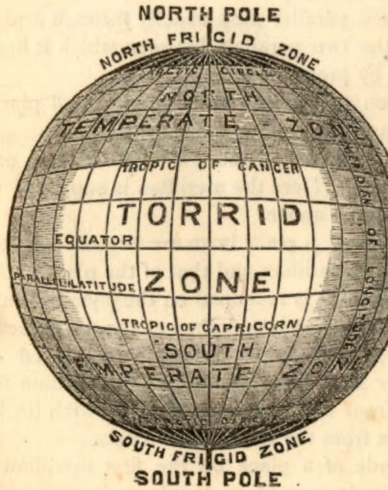
The Tropics of Cancer and Capricorn are the northern and southern boundaries of the Torrid Zone.

The **Arctic Circle** is a parallel of latitude 23½ degrees from the North Pole. It is the southern boundary of the North Frigid Zone.

The North Temperate Zone is bounded by the Arctic Circle on the north, and by the Tropic of Cancer on the south.

The **Antarctic Circle** is a parallel of latitude 23½ degrees from the South Pole. It is the northern boundary of the South Frigid Zone.

The South Temperate Zone is bounded by the Antarctic Circle on the south, and by the Tropic of Capricorn on the north.



LATITUDE is the distance of any place, measured in degrees, north or south of the equator.

The latitude of a place is an arc of the meridian intercepted between the equator and the place, and is called north or south, according as the place is situated in the northern or southern hemisphere. It can never exceed 90 degrees, which is the distance from the poles to the equator. The latitude of a place on the equator is 0°; that of the poles is 90° N. or S.; that of a place midway between the equator and the poles is 45° N. or S.

On a globe, latitude is reckoned by degrees and minutes on the brass meridian. In maps it is reckoned at the sides. To find the latitude of a place on a map it is only necessary to observe the number of the parallel which passes through it, and notice whether the place is north or south of the equator.

Thus, if we want the latitude of New York, we notice that it is north of the equator, and that the parallel of latitude marked 40 at the side of the map passes just below it: hence its latitude is about 40° N. (40° 42′).

If no marked parallel pass exactly through a place, the distances from the two parallels between which it lies is a matter of calculation by proportion.

All places on the same parallel, that is, all places due east and west of each other, have the same latitude.

LONGITUDE is the distance of a place east or west from the first meridian. Here the meridian is supposed to be a half-circle, as explained above.

The longitude of a place is an arc of the equator contained between the first meridian and that of the place. On globes or maps of the world it is reckoned on the equator, but in maps of portions of the earth it is reckoned at the top or bottom.

Geographers in different countries have fixed on different places for the **first meridian.** In Great Britain the longitude is reckoned from the meridian of Greenwich (in Kent). The French reckon from the meridian of Paris.

The longitude of a place on the first meridian is 0°. The greatest longitude any place can have is 180°, or half the circumference of the globe.

To find the longitude of a place it is necessary to observe (on the equator, or at the top or bottom of the map) the number of the meridian which passes through it, and to notice whether the place is east or west of the first meridian.

Thus, if we want the longitude of New York, we notice that it lies W. of the meridian of Greenwich (marked 0), and between the meridians numbered 70 and 80 (somewhat nearer to the former than the latter). By observing the relative distances from these two meridians, we calculate that the longitude is about 74° W.

All places on the same meridian, that is all places due north or south of each other, have the same longitude.

Exercise.

1. Find the latitude and longitude of the following places. (The answers will be found at the end of the Section, at page 14).

Calcutta (India);	Cape Horn;	Trinidad;
Yarmouth;	Vienna;	Bristol;
Delhi;	Rome;	Moscow;
St. Helena;	Malta;	Buenos Ayres (S. America.)

2. Give the names of places which have the following latitude and longitude.

Latitude.	*Longitude.*
34° 29′ S.	18° 23′ E.
31° 47′ N.	35° 20′ E.
53° 20′ N.	6° 6′ W.
33° 45′ S.	78° 37′ W.
12° 1′ S.	76° 49′ W.
39° 54′ N.	116° 27′ E.
46° 48′ N.	71° 10′ W.
52° 14′ N.	21° 0′ E.
51° 46′ N.	1° 16′ W.
52° 42′ N.	8° 35′ W.
29° 2′ S.	168° 10′ E.
22° 54′ S.	42° 44′ W.

By means of latitude and longitude the position of a place may be described with the greatest exactness. They are especially useful in marking positions on the ocean, where there are no points convenient for comparison except a few islands dotted here and there on the generally unbroken surface. In 1865 the Atlantic telegraph cable broke as it was being paid out into the deep water, and sank to the bottom, a depth of many thousands of fathoms. The sailors, who were obliged to leave the cable submerged and to come away, could not mark the place, or set up a post, as they might have done on land. But they were able to take the latitude and longitude, by means of instruments, and a year or two afterwards men came to the spot, which they found without any difficulty, and by means of grappling apparatus recovered the lost cable from the depths of the ocean.

We have already seen that degrees of latitude do not vary in length (or very slightly), since they are calculated by arcs of the meridians, which are all great circles of the same length. The length of a degree of latitude is rather more than 69 miles.

Degrees of longitude vary in length, since they are measured by arcs of the parallels of latitude, which are small circles gradually decreasing in magnitude from the equator towards each pole. The following table shows the various lengths of a degree of longitude at different parallels of latitude.

			English Miles.
On the Equator a degree of longitude measures			69·07.
At 10° of latitude	"	"	67·95.
At 20° "	"	"	64·84.
At 30° "	"	"	59·75.
At 40° "	"	"	52·85.
At 50° "	"	"	44·35.
At 60° "	"	"	34·50.
At 70° "	"	"	23·60.
At 80° "	"	"	11·98.
At 90° "	"	"	0·00.

Latitude may be found by observing the height of the pole-star, which shines almost immediately over the North Pole. An observer at the North Pole would have the pole-star almost directly over head. If he travelled from the North Pole to the equator, the pole-star would appear to descend in the heavens just as many degrees as he passed over the curved surface of the earth. When he arrived at 70 degrees N. latitude, the pole-star would have sunk 20 degrees in the heavens, and so on till he reached the equator, when the pole-star would shine on the horizon. Hence, to find the latitude of a place north of the equator it is only necessary to take the altitude of the pole-star in degrees. Thus, if the altitude of the pole-star be 37° the latitude of the place is 37°.

Latitude may also be found by observing the altitude of the sun, or any star whose declination (or celestial latitude) is given in the nautical almanac, at any given moment. The difference between the declination or altitude of the heavenly body at Greenwich and at the place where the observation is taken, gives the difference of latitude of the two places.

Longitude is found by means of chronometers, which give the mean time at Greenwich. Noon at any place is the moment when the sun crosses the meridian. The sun appears to travel in a circle round the earth in 24 hours; hence he passes over 360° in 24 hours, or 15° per hour. Thus, if the difference of noon at two places be one hour, the difference of longitude is 15°; if two hours, 30°, and so on, reckoning 15° degrees for each hour. If the noon be later than at Greenwich the place is in west longitude; if it be earlier the place is in east longitude. Now, an observer at any given place can, by means of instruments, ascertain the exact moment at which the sun arrives at his greatest altitude, which is that at which he crosses the meridian of the place. His chronometers give him the exact time at Greenwich, and he can then calculate the longitude. Let us suppose, for example, that the sun crosses the meridian at 3.20 p.m., that is, the time of noon is later by $3\frac{1}{3}$ hours than at Greenwich. Then reckoning 15 degrees for each hour, he

obtains the longitude 50° W. If he also finds that the sun is say 20° higher in the heavens than at Greenwich, he also knows that he is 20 degrees further south than Greenwich, or that the latitude is 20° less.

It will readily be seen that if the difference of time between any two places be known, their difference of longitude is also known, and *vice versâ*.

Answers to Exercise at p. 11.

		Latitude.	*Longitude.*
1.	Calcutta	22° 35′ N.	88° 29′ E.
	Cape Horn	55° 58′ S.	63° 0′ W.
	Trinidad	11° 15′ N.	126° 42′ W.
	Yarmouth	52° 55′ N.	1° 40′ E.
	Vienna	48° 13′ N.	16° 23′ E.
	Bristol	51° 28′ N.	2° 30′ W.
	Delhi	28° 37′ N.	77° 40′ E.
	Rome	41° 54′ N.	12° 29′ E.
	Moscow	55° 46′ N.	37° 33′ E.
	St. Helena	15° 55′ S.	5° 49′ W.
	Malta	35° 54′ N.	14° 28′ E.
	Buenos Ayres	34° 35′ S.	58° 31′ W.

2. Cape of Good Hope, Jerusalem, Dublin, Juan Fernandez, Lima, Pekin, Quebec, Warsaw, Oxford, Limerick, Norfolk Island, Rio Janeiro.

ASTRONOMY.

DEFINITIONS.

Astronomy is the science which treats of the heavenly bodies, namely, the Sun, the Moon, the Planets, and the Stars; describing their magnitudes, distances, motions, and the laws by which they are governed.

A **Plane, or Plane Superficies,** is a surface in which, if any two points are taken, the straight line joining them lies entirely in that surface.

A **Circle** is a plane figure contained by one line, which is called the *Circumference*, and is such that all straight lines drawn from a certain point within the figure to the circumference are equal to one another. This point is called the *Centre* of the circle.

Any straight line drawn from the centre to the circumference is called a **Radius** of the circle. The plural of radius is *radii*. All the radii of a circle are equal to one another.

A **Diameter** of a circle is a straight line drawn through the centre, and terminated both ways by the circumference.

The **Plane of a circle** is an imaginary flat surface supposed to join every part of the circumference with the centre.

Any portion of the circumference of a circle is called an **Arc.**

For the purposes of measurement, the circumference of a circle is supposed to be divided into 360 parts, each of which is called a degree. Each degree is divided into sixty minutes, and each minute into sixty seconds. These are generally ex-

pressed by signs, thus :—54° 3′ 25″ signifies 54 degrees, 3 minutes, 25 seconds.

The terms *degree*, *minute*, *second*, do not express any fixed measurements. The length of each depends on the magnitude of the circle.

The half of a circle is called a **Semicircle.**

A **Globe,** or **Sphere,** is a solid body contained under a single surface, every point in which is equally distant from a point situated within the body, and called the centre.

A Globe, or Sphere, may be supposed to be described by the revolution of a semicircle about its diameter, which remains unmoved.

A **Great Circle** of a sphere is one whose plane passes through the centre of the sphere. A great circle divides the surface of a sphere into two equal parts.

A **Small Circle** is one whose plane does not pass through the centre of the sphere.

When we look towards the sky, it appears to have the form of the inner or concave surface of a large globe or sphere, of which we are placed in the centre. For the purposes of calculation and description, imaginary lines are supposed to be drawn on the surface of the heavens, corresponding in some measure with those supposed to be drawn on the surface of the Earth.

If we imagine the earth's axis to be extended or *produced* both ways till it meets the sky in two opposite points, we shall then have two points in the heavens corresponding with the North and South poles of the Earth. These are called the **North Pole** of the Heavens, and the **South Pole** of the Heavens.

In these northern latitudes we never see the position of the south pole of the heavens, but that of the north pole is always visible. It is situated very near to the Pole Star, which may easily be found on a clear night.

The stars in the sky are arranged in groups supposed to form figures of animals and other well-known objects. These groups of stars are called **Constellations.** One of the most conspicuous of these is the *Great Bear*, which shines in the northern heavens, and is chiefly distinguished by seven bright stars, called *Charles's Wain*, or the *Plough*. The two stars on the right hand side (numbered 6 and 7 in the diagram) are named the *Pointers*, because they point to the pole-star. If we imagine a line to be drawn through them and carried on for some distance, it will pass close to the pole-star (8).

THE GREAT BEAR AND POLE-STAR.

If we observe the stars for some time on a clear night, we shall find that they appear to move round the pole-star, which alone remains fixed in the sky. The others revolve round it in circles. This motion is, however, only *apparent*. It is caused by the rotation of the earth on its axis once in twenty-four hours. It is the earth which really moves from west to east, causing an apparent motion of the sun, the moon, and the stars from east to west.

Let us now imagine a great circle to be drawn round the heavens exactly midway between the north and south pole.

This great circle is called the **Equinoctial.** It corresponds with the equator of the earth. If we suppose the plane of the equator produced so as to cut the sky, it would meet the equinoctial in every point. Hence the equator and the equinoctial are sometimes termed the **Terrestrial Equator** and the **Celestial Equator.**

A parallel series of small circles is supposed to be drawn in the heavens north and south of the equinoctial, and between it and the poles. These are called **Parallels of Declination,** and correspond with the parallels of latitude on the surface of the earth. By means of these the celestial latitude, or **Declination,** of a point in the sky or of a heavenly body may be described. A point is said to be in north or south declination according as it is situated to the north or south of the equinoctial. Distance north or south of this line is measured by degrees, minutes, and seconds, as on the surface of the earth.

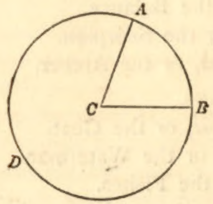
A series of great circles are supposed to be drawn through the poles and round the heavens. These are called **Celestial Meridians,** and correspond with the meridians of longitude on the surface of the earth. By means of these the celestial longitude, or **Right Ascension,** of a point in the sky or of a heavenly body may be described. The measurement is again in degrees, minutes, and seconds, and is reckoned to the east from the first celestial meridian, which crosses the equinoctial at the first point of Aries, or the Vernal Equinox. (*See* pages 31 and 32.)

Thus, if a point in the sky is described as being in right ascension 250° and south declination 35°, we know that it is situated 250 degrees to the east of the first celestial meridian, and 35 degrees to the south of the equinoctial. In this way an observer who is acquainted with the position of these lines on the sky is able to determine the position of the point.

The sun appears to move round a great circle of the heavens in the course of one year. This circle is called the **Ecliptic**; it is properly the path which the earth would appear to take if viewed from the sun, since it is the Earth which moves round the Sun, and not the Sun round the Earth.

Two planes may either coincide with each other, or be parallel to each other, or cut each other at a certain angle.

Angles are measured by the number of degrees in the corresponding arc of a circle drawn with any radius, and having its centre at the point of intersection of the two lines which form the angle. Thus, if A C B be an angle, and A B D be any



circle with centre C, then the angle A C B is measured by the number of degrees, minutes, and seconds in the arc A B. An angle subtending the quarter of a circle is a right angle, and contains 90 degrees (360° ÷ 4).

The plane of the equinoctial is inclined to that of the ecliptic at an angle of 23½ degrees. They cut each other in two opposite points, called the *equinoctial points*, or *equinoxes.*

The **Zodiac** is a belt or girdle of the heavens extending about 9 degrees on each side of the ecliptic. The apparent paths of the sun, the moon, and the planets lie within the Zodiac.

The ecliptic and the zodiac are divided into twelve equal parts, called the **Signs of the Zodiac,** marked by constellations named chiefly after various living beings.

The sun appears to travel through each of these signs in succession, according to the month, and the season of the year.

The names of the twelve signs of the Zodiac are as follows :—

A. **Northern Signs,** situated to the north of the equinoctial.

(1) Spring Signs.

Aries, or the Ram.
Taurus, or the Bull.
Gemini, or the Twins.

(2) SUMMER SIGNS.
Cancer, or the Crab.
Leo, or the Lion.
Virgo, or the Virgin.

B. **Southern Signs.**

(3) AUTUMN SIGNS.
Libra, or the Balance.
Scorpio, or the Scorpion.
Sagittarius, or the Archer.

(4) WINTER SIGNS.
Capricornus, or the Goat.
Aquarius, or the Waterman.
Pisces, or the Fishes.

The following lines will help our readers to remember them:

"The Ram, the Bull, the Heavenly Twins,
And next the Crab, the Lion shines,
The Virgin and the Scales.
The Scorpion, Archer, and He-goat,
The Man that bears the water-pot,
And Fish with glittering tails."

The **Zenith** is the point in the heavens exactly over the head of an observer on the earth's surface.

The **Nadir** is the point in the heavens exactly under the feet of an observer on the earth's surface. It is therefore precisely opposite to the zenith, and is of course invisible to the observer, being hidden from him by the mass of the earth.

The **Sensible**, or visible, **Horizon** is the circle which bounds the view of an observer, where the sky appears to meet the earth or sea.

The **Rational**, or true, **Horizon** is a great circle of the heavens formed by an imaginary plane passing through the centre of the earth parallel to the sensible horizon.

The sensible horizon extends over a radius of only a few miles, more or less, according to the height of the observer

above the ordinary level of the Earth; but the rational horizon divides the sphere of the heavens into two equal parts.

The zenith and nadir are the two poles of the rational horizon at any point on the earth's surface.

THE SOLAR SYSTEM.

If we observe the heavenly bodies for a number of consecutive nights, we shall find that they may be distinguished as belonging to two divisions, namely:—

1. Those which keep the same relative positions with regard to each other. They appear to move round the pole-star from east to west, it is true, but they always remain at exactly the same distance from each other, and form groups or constellations, each of which retains the same form. These are the **Fixed Stars.**

2. Those which change their relative positions with regard to each other, and appear to travel through the signs of the Zodiac, being sometimes in one constellation and sometimes in another. These bodies consist of—

(*a*) The **Moon**, which revolves round the Earth, and

(*b*) The **Planets**, which revolve round the Sun.

The Fixed Stars may be distinguished from the Planets by their twinkling or tremulous light. The planets shine with a steady, unintermittent light.

The former are believed to be suns, each shining by its own light. The latter are dull bodies like the Earth, shining only by light falling on them from the sun.

The **Earth** is one of the planets. It revolves round the sun like the other planets.

The **Sun**, together with the planets and their attendant bodies, make up the Solar System (Lat. *Sol*, the sun).

The fixed stars lie outside of, and at a vast distance from, the solar system, and, as far as we know, have little or no dependence on it.

This System of the Universe is called the **Copernican System**,

because it was given to the world by Nicholas Copernicus, who lived at Thorn, in Prussia, in the 15th century. It is said, however, to have been taught by Pythagoras, a famous Greek philosopher, who lived 500 years before the Christian era. His teaching was not, however, accepted by the ancients, who generally held the views of Ptolemy, of Alexandria in Egypt. This astronomer held that the Earth is the centre of the Universe, and that the Sun, the Moon, the Planets, and the Stars revolve round it as they appear to do in the sky.

These and other erroneous notions on the subject of the heavenly bodies were finally superseded by the Copernican System, which has been confirmed and established on an immovable basis by the observations and calculations of modern astronomers.

I. THE SUN.

The Sun occupies the centre of the Solar System. The Earth and the other Planets revolve round it, each in its separate path or **Orbit** (Lat. *orbis*, a wheel or circle). The Sun is a sphere, or globe, far exceeding in bulk any one of the bodies which receive their light and heat from it. It is nearly 700 times greater than the Earth and all the other planets together.

The diameter of the Sun is 852,600 miles, or nearly one hundred and ten times greater than that of the Earth.

The Sun is supposed to be an immense solid body, whose nature is imperfectly known, surrounded by a gaseous atmosphere heated to an intense degree, and subject to storms of a terrific character. Immense spots often appear on the surface of the sun. Their dark appearance is supposed to be caused by vast gaps in the fiery atmosphere, and the laying bare of the body of the Sun beneath. Sometimes a spot is shaded off into two or more degrees of darkness (surrounding each other), according to the depth to which the luminous atmosphere has been removed in the several portions of the spot. In cases of this kind the dark centre is called the *nucleus;* next come the *umbra* and *penumbra*, and the whole is encircled by the full

brightness, or *photosphere.* Constant changes are going on in each spot, and in each portion of it, both in size and shape. These spots are of various sizes ; some have been observed whose diameters must have measured 40 or 50 thousands of miles.

During the last twenty years, through a process called **Spectrum Analysis**, experiments have been carried on by which the light from a heavenly body can be analysed, and the substances which exist in it in a state of incandescence can be determined by the colour of the rays emitted. By means of solar spectra it has been found that Sodium, Iron, Magnesium, Copper, Zinc, Hydrogen, and several other elements are present in the Sun.

The Sun is not exactly spherical ; it is an oblate spheroid, flattened at the poles, like the Earth and the other planets.

Observations of the spots on the Sun's disc have shown that it rotates on its axis. Spots have been found to appear on one side of the Sun's surface, to travel gradually across it, and then to disappear on the other side. In this way it has been discovered that the Sun rotates on its axis in a period of 25 days 8 hours, nearly.

The Sun's axis is inclined to the plane of the earth's orbit at an angle of 82° 40′, being thus 7° 20′ out of the perpendicular.

As we have already observed, the sun appears to travel along a path in the sky called the Ecliptic, through the signs of the Zodiac. This is only an apparent motion ; it is caused by a real motion of the earth, as one of the planets, in its orbit round the Sun.

II. THE EARTH.

1. FORM, SIZE, POSITION.

Form.—As explained elsewhere, the Earth is an Oblate Spheroid, flattened at the poles, like an orange.

Size.—The diameter of the Earth at the Equator is about 7,900 miles. At the poles the diameter is about 26 miles less. The circumference of the Earth is nearly 25,000 miles.

Position.—The Earth's distance from the Sun is about 91,500,000 miles. This is the *mean* distance. The Earth is more distant from the Sun at one part of the year than at another.

2. ROTATION. DAY AND NIGHT.

The earth turns round, or *rotates*, on an imaginary line called its **Axis**, once in every twenty-four hours.

As the Earth is of the form of a sphere, or spheroid, one half of it is turned towards the Sun, while the other half is turned away from it. Hence one half of the Earth is in the light while the other half is in darkness.

If the Earth remained perfectly still, the same one half would always be in the light, and the same other half would always be in darkness. But the Earth rotates on its axis, causing the half of the world which was before in the light to move into the darkness, and the half which was before in the darkness to move into the light.

The time when it is light, is called **Day**; and the time when it is dark, is called **Night**. Day is caused by the shining of the Sun; Night is caused by the withdrawal of the Sun. A person standing on the light side of the Earth can see the sun shining in the sky. But a person standing on the dark side of the Earth cannot see the sun, because it is shining on the other side.

It is always day on one side of the Earth, and it is always night on one side of the Earth; for the Sun never ceases to shine, and he can shine only on one-half of the world at the same time. When it is day on one-half of the Earth, it is night on the other.

If we observe the course of the Sun, we see that he appears to rise in the east in the morning, move gradually round to the south at noon, and then pass slowly on and set in the west at evening time.

This motion of the Sun is not real, but apparent. It is not the Sun which moves, but the Earth, rotating on its axis.

We do not feel the Earth moving, because it moves so steadily

and quietly. There is no shaking, or jolting, or noise. When we travel in an express train on a smooth line of railway we are scarcely conscious of any motion of our own, and if we look out of the carriage window the trees, houses, and telegraph posts seem flying past us. They appear to be moving from us, while we seem to be remaining in the same place. If we are travelling from west to east, the trees and other objects seem flying the other way, from east to west. Similarly the real rotatory motion of the Earth from west to east occasions an apparent motion of the sun in the contrary direction, from east to west.

If the Earth's axis were exactly perpendicular to the plane of its orbit, there would be equal day and night (12 hours of each) on every part of the Earth's surface all the year round. But the axis is inclined somewhat from the perpendicular, and this deviation from the vertical causes the days to be longer in summer and shorter in winter, and the nights to be shorter in summer and longer in winter, as is explained in the chapter which treats of Seasons and their causes.

Day and Night do not come on all at once exactly at sunrise and sunset. There are two short periods in every twenty four hours during which Day and Night are gradually passing one into the other. This is during the times called **Twilight**. In the morning twilight, a short interval before sunrise, night is gradually passing away, and the Morning Star (Lucifer) announces the approach of the Sun. In the evening twilight, another short interval after sunset, the light is gradually fading away into darkness, and the Evening Star (Hesperus) tells us that night is at hand.

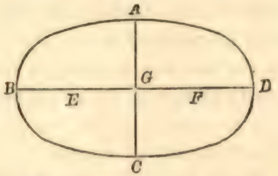
It is the rotation of the Earth on its axis which causes our planet to take the form of an oblate spheroid. The parts of the Earth's surface near to the equator rotate in larger circles than those near the poles. Hence, having a larger distance to travel in the same time, the parts near the equator move with a greater velocity than those near the poles. Thus the greater centrifugal force (or tendency to fly from the centre of rotation) at the

equator causes the equatorial portions of the Earth's surface to bulge out, while the polar regions are in like manner depressed. The same remarks apply to the planets and other bodies which rotate on their axes.

3. ORBIT. ELLIPSE.

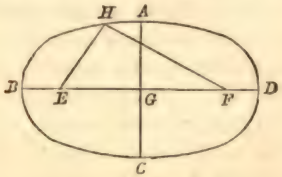
The path in which the Earth moves round the Sun is not exactly a circle. It is an **ellipse**. The Earth, and each of the other planets revolves round the Sun in elliptical orbits.

An ellipse is a figure of an oval shape, formed by cutting a cone by a plane which cuts all sides but is not parallel to the base. Its length is greater than its breadth. A B C D is an ellipse, of which the length, or longer diameter, is B D, and the



breadth, or shorter diameter, is A C. B D is usually called the *conjugate axis* and A C the *transverse axis*. An ellipse is regarded as having two *foci*, or centres. In this respect it differs from a circle, which has only one. If E and F be the foci, then G E or G F, the distance of each focus from the point in which the axes intersect, is called the *eccentricity* of the ellipse. The greater the eccentricity of an ellipse, the greater is its deviation from a circle.

An ellipse may be drawn in the following manner. Take E F

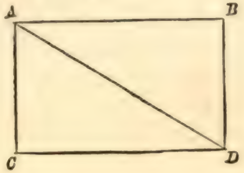


double of the eccentricity of the ellipse. Fix a pin in each of

the points E, F. Then take a string of the length of the transverse axis, and fasten its ends on the two pins E and F. Now stretch the string to its full extent, so that it reaches to a point in the required curve at H; and by moving a pencil round within the string, keeping the latter always stretched out, the ellipse will be traced.

Each of the planets, including the earth, moves in an orbit which is an ellipse of only small eccentricity. Some of their orbits are more eccentric than others, but not one of them differs very widely from a circle. The Sun is situated in one of the foci of each ellipse representing the orbit of a planet. Thus, if a planet move in the orbit A B C D, the Sun is situated at E, or at F. It will easily be seen that a planet is nearer to the Sun during one part of its revolution than at another. For, supposing the Sun to be situated at E, the distance of the planet when at D is greater than its distance at B. In the former case the distance is E D, and in the latter E B. The point on a planet's orbit where it is at its greatest distance from the sun is termed the **Aphelion** (Gr. *apo*, from; *helios*, the Sun) of the planet. The point where it is at its least distance is called the **Perihelion** (Gr. *peri*, around; *helios*, the Sun) of the planet. In the last figure the point D represents the aphelion, and B the perihelion of the planet revolving round the Sun at E in an orbit A B C D.

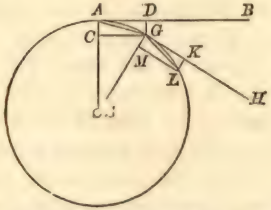
The revolution of the Earth round the Sun is caused by the combined influence of two distinct forces. It is a well-known principle in mechanics, that if a body be impelled by two forces acting in two different, but not opposite, directions, the body will move in a path situated between the two directions. Thus, if a body at A be impelled at the same time by a force acting in the direction A B, and another acting in the direction A C, it



will move in neither of those directions, but in a path A D lying between A B and A C. If the force acting along A B be greater than the force acting along A C (as indicated by the line A B being longer than the line A C), then the path A D will be nearer to A B than to A C, and *vice versa.*

The Earth is acted upon by two forces constantly in operation. The attraction of the Sun draws it towards the centre of the solar system. Besides this, the earth has a tendency to fly off in a straight line in a direction at right angles to a line drawn from it to the Sun. We know not by what exact means this impulse was originally given to it, but must simply suppose that it was imparted by the Almighty Creator of all things.

Let us suppose the Sun to be at S, and the Earth at A, and that a force is acting upon it in the direction A B. The attrac-



tion of the Sun acts in the direction A S. The Earth will not move in either of the directions A B, A S, but in a direction lying between the two. Consequently, at the end of a given time the Earth will be found at G.

The attraction of the Sun will now act in the direction G S, while the Earth has again a tendency to move in the direction G H, at right angles to G S. It will again move in an intermediate direction, and at the end of another similar period of time will be found at L. A, G, L are points on a circle, and any number of intermediate points in it may be found by making rectangles similar to A C G D, G M L K, but smaller.

The explanation given above will impart a general knowledge of a subject which cannot be clearly understood without the aid of mechanics. It may be further illustrated by considering a

stone tied to the end of a string and twirled round in a boy's hand. Here the stone is acted upon by two forces. The string pulls the stone towards the boy's hand, while the direct impulse acting on the stone tends to make it fly off in a line at right angles to the string; indeed, if the boy were to let go the string, the stone would actually fly off in that direction. Here there are two forces; one is the **centripetal force** (Lat. *peto*, I seek), acting *towards* the centre, and the **centrifugal force** (Lat. *fugio*, I flee), acting *away from* the centre. The stone moves in a circle, in a direction between the lines of the two forces.

Thus the Earth moves round the Sun in an orbit which is nearly circular. Why it moves in an ellipse which brings it nearer to the Sun in one part of its course than another, cannot be understood without considerable mathematical knowledge. The following explanation will be sufficient here. Sometimes the attraction of the Sun overcomes the centrifugal force to a certain extent. This causes the Earth to approach nearer to the Sun, and at the same time increases its velocity. This increased velocity, on the other hand, also increases the centrifugal force, just as the faster the stone is whirled round on the string, the greater is its tendency to fly off (in a tangent). This increase of the centrifugal force counteracts the augmented attraction, and the Earth is borne back again to its former distance from the Sun.

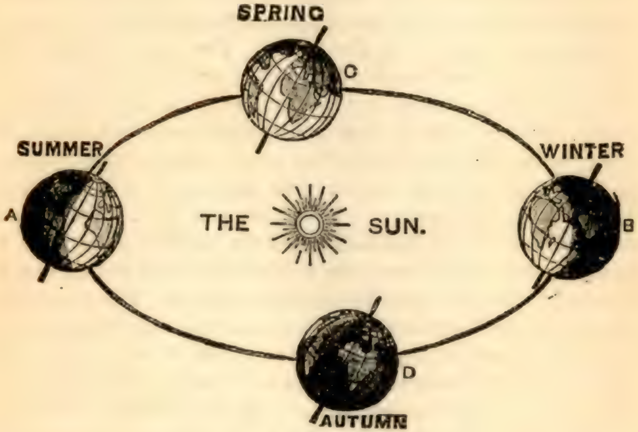
4. SEASONS.

The Earth moves round the Sun in the space of a year. If the axis of the Earth were perpendicular to the plane of its orbit, it is evident that the length of days and nights would be equal all the year round on every part of the Earth's surface. For then every part of the Earth's surface would, by the rotation of our planet on its axis, be turned towards the Sun for twelve hours, and away from the Sun for twelve hours, during each day.

But the axis of the Earth is inclined about $23\frac{1}{2}°$ out of the perpendicular. In other words, the plane of the Earth's equator is inclined to the plane of the equinoctial at an angle of about

$23\frac{1}{2}°$. The axis of the Earth continues parallel to itself during the whole of each annual revolution; that is to say, it is inclined to the plane of the Earth's orbit at the same angle during the whole year.

The consequences of this inclination of the Earth's axis will be seen from the accompanying diagram.



THE SEASONS.

When the Earth is at A, the northern half is, by reason of the inclination of the axis, turned towards the Sun, while the southern half is turned away from the Sun. Hence, as the Earth revolves on its axis, the portions of the Earth's surface near the North Pole remain in the light, and those near the South Pole remain in darkness. When the Earth is at A, it is summer in the northern hemisphere, and winter in the southern hemisphere. At this part of the year the Sun never sets near the North Pole, and never rises near the South Pole. Between the north polar and equatorial regions the days are long and the nights are short, because a larger part of the northern

hemisphere is in the light than in the darkness. For a contrary reason, between the south polar and equatorial regions the days are short and the nights are long.

When the Earth arrives at B, a complete change has taken place, though the axis of the Earth still preserves the same inclination to the plane of its orbit. Now the northern hemisphere is turned away from the Sun, while the southern hemisphere is turned towards it. This is at the time of our winter, when the Sun never rises on the North Pole and never sets on the South Pole; when the days are short and the nights are long in the North Temperate regions, while the days are long and the nights are short in the South Temperate regions.

When the Earth is at C and at D, the North and South poles are neither inclined towards nor from the Sun. In these positions we have the northern Spring and Autumn, when the days and nights are equal all over the Earth.

Let us suppose the Earth to commence its annual revolution at C. The Sun is then entering Aries; it is the 21st of March, the time of the **Vernal Equinox**, when the days and nights are equal throughout the world. The Earth travels towards A, and the Sun passes through Aries, Taurus, and Gemini. When the Sun arrives at Cancer, the Earth has moved to A. The North Polar regions have become more and more turned towards the Sun, and the northern days gradually lengthened. The Earth arrives at A on June 21st, the time of our longest day, or **Summer Solstice.** While the Earth moves from A to D, the Sun travels through Cancer, Leo, and Virgo. When he arrives at Libra, the Earth is at D. This is at the time of the **Autumnal Equinox**, Sept. 22nd, when the days and nights are again equal throughout the world. As the Earth journeys from D to B, the Sun passes through Libra, Scorpio, and Sagittarius. When he arrives at Capricorn, the Earth is at B. The northern days have been gradually shortening, while the southern days have been lengthening in the same proportion. The earth arrives at B on December 22nd, which is the time of **Winter Solstice.** Then the northern days are shortest, and the southern days

are longest. The Earth pursues its course from B to C, while the Sun passes through Capricorn, Aquarius, and Pisces; till at C it again enters the sign Aries.

Thus the inclination of the Earth's Axis gives rise to four seasons, which take place at opposite times in the Northern and Southern Hemispheres.

In our Spring the days are lengthening, the northern parts of the Earth are becoming more and more inclined towards the Sun, which consequently shines more and more overhead.

In our Summer, the days have reached their greatest length, and begin to get shorter.

In our Autumn, the days gradually become shorter, the northern parts of the Earth are becoming less and less inclined towards the Sun, which consequently shines less and less overhead.

In our Winter, the days have reached their least length, and begin to get longer.

It will be evident from the diagram that the Equatorial regions of the Earth are always turned towards the Sun. During the whole year exactly one-half of the equator is in the light, and one-half is in darkness. Hence at the equator the days and nights are of equal length all the year round. On the Equator itself there is no change of seasons. On March 21st the Sun is vertical at the Equator. Then he gradually rises higher in the northern hemisphere, till on June 21st he is vertical at the Tropic of Cancer. He then gradually sinks towards the south, and on September 22nd he is again vertical at the Equator. During the next quarter he sinks gradually in the southern hemisphere, till on December 22nd he is vertical at the Tropic of Capricorn. Then he rises again towards the north, and on March 21st he is once more vertical at the Equator.

The times at which the Sun is vertical at the equator are called the Equinoxes (Lat. *aequus*, equal; *nox*, night), because the nights are then equal all over the earth. There are two equinoxes—the Vernal Equinox, March 21st, and the Autumnal Equinox, September 22nd

The times at which the Sun is vertical at the tropics are called the Solstices (Lat. *sol*, the Sun; *sto*, I stand), because then the Sun appears to stop in its northward or southward course, before turning in the opposite direction. There are two Solstices—the Summer Solstice, June 21st, when the Sun has reached his most northerly limit, and is vertical at the Tropic of Cancer; and the Winter Solstice, December 22nd, when the Sun has reached his most southerly limit, and is vertical at the Tropic of Capricorn.

The **Tropics** (Gr. *trepo*, I turn) are so called because they mark the boundaries of the Sun's path, and the positions which it attains before turning towards the north or towards the south. The distance of the tropics from the equator, $23\frac{1}{2}°$, necessarily coincides with the deviation of the Earth's axis from a perpendicular to the plane of its orbit.

The greater heat of our summer is not caused by the earth being then at a less distance from the Sun than during winter, for we are actually further from the Sun in summer than in winter. The Earth's orbit is, as we have already seen, an ellipse, of which the Sun occupies one of the foci. At Midsummer the Earth is in aphelion, or the greatest distance from the Sun, while on December 22nd it is in perihelion, or the least distance from the Sun. Thus we are actually more than three millions of miles further from the Sun at Midsummer than at Midwinter. This causes the Sun to appear somewhat larger in the middle of winter than in the middle of summer. The Sun's apparent diameter on December 22nd is 32′ 47″, while on June 21st it is only 31′ 40″.

The greater heat of summer and the less heat of winter are due to two causes.

1. In summer the Sun rises to a greater height above the horizon, and therefore his rays fall more perpendicularly upon the northern part of the Earth than in the winter.

2. In summer the days are very long, and the nights short; hence the Earth and the air are heated by the Sun during the day more than they are cooled in the night. From this cause

there is an *accumulation of heat*, and the Earth becomes warmer day after day. This process continues for some time after the longest day; hence the greatest heat of summer is not arrived at till some weeks after the summer solstice, when the Sun is at his highest elevation in the northern hemisphere.

An attentive examination of the diagram will show that during the Earth's progress from D to C, the rotation of its axis will never turn the north pole towards the Sun, nor the south pole away from it. On the other hand, during the Earth's progress from C to D the rotation of its axis will never turn the north pole away from the Sun, nor the south pole towards it. Hence at the poles the year consists of one long day of six months' duration, and one long night also of six months' duration.

At the equator the days and nights are of equal length all the year round. At the poles they are each six months in length. From the equator to the poles the inequality between the lengths of the days and nights in summer and winter gradually increases in proportion to the latitude. The greater the latitude, the longer are the days in summer and the nights in winter, and *vice versa*.

5. ATMOSPHERE.

The Earth is surrounded by an envelope composed of a thin fluid or gaseous substance called air. The whole body of air surrounding the Earth is termed the **Atmosphere** (Gr. *atmos*, vapour; *sphaira*, a sphere).

Height. Various experiments have been tried, with a view of ascertaining the height to which the atmosphere surrounds the Earth. Many estimates have been made, varying from 45 to more than 200 miles; but no reliable result has yet been arrived at.

Density. As air is very elastic, it yields easily to pressure. Hence the lower strata, being pressed down by those above, are much denser than the upper strata. Hence the density, and consequently the weight, of any portion of the atmosphere depends chiefly on its height above the surface of the earth. Thus, the height of a mountain may be ascertained by means of a barometer, or instrument for measuring the weight of the atmosphere.

Weight. The weight of the air can easily be discovered by means of a hollow globe, so arranged that the air can be exhausted from it with the aid of an air-pump. If the globe be weighed before and after the air has been exhausted, the difference of weights will give the weight of the air required to fill the globe, whose cubic contents are supposed to be known. Thus, the weight of 100 cubic inches of dry air at 60° F. when the barometer is at 30 inches, has been found to be 31·074 grains. When the temperature is greater, or the mercury in the barometer lower, the weight is proportionately less.

Pressure. According to the laws of fluids, the air presses with an equal weight in all directions on bodies immersed in it, according to the height of the fluid above any given body. The pressure of the atmosphere is of course greater at the surface of the earth than at any higher point, and it is greater still in a mine or pit. In the barometer at the surface of the earth a column of mercury about 30 inches in height is supported by the pressure of the atmosphere. A column of mercury 30 inches in height and having a horizontal section of 1 square inch, weighs nearly 15lbs. Hence the pressure of the atmosphere at the surface of the earth is equal to nearly 15lbs. (14·73 lbs.) on every square inch. The actual pressure, however, varies according to the differing conditions of the atmosphere, and this constant change causes the mercury to rise and fall in the barometer.

Composition. The air is composed mainly of two gases, oxygen and nitrogen, with a small quantity of carbonic acid. The following table gives the approximate proportions of each of these substances, by volumn and by weight, taking 100 parts of air in each case:—

	Volume.	Weight.
Nitrogen.	79·02.	76·84.
Oxygen.	20·94.	23·10.
Carbonic Acid.	·04.	·06.

Air is seldom or never found quite dry and pure; it usually holds a certain amount of vapour, smoke, and other impurities.

6. DIVISIONS OF TIME.

Sidereal Day. The rotation of the Earth is always performed in exactly the same time, 23 hours, 56 minutes, 4 seconds, nearly. This is the time during which any meridian on the Earth's surface will revolve from its position opposite to any fixed star to the same place again. This space of time is called a sidereal day. Every sidereal day is of exactly the same length.

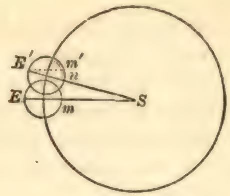
Solar Day. The period during which any meridian on the Earth's surface will revolve from its position opposite to the Sun to the same place again, is termed a solar day.

The solar day is different in length from the sidereal day, and varies in different parts of the year, according to the position of the Earth in its orbit.

The distance of the fixed stars from us is so great that the diameter of the earth's orbit, though more than 180 millions of miles, is but a point in comparison; and therefore any meridian on the Earth's surface will revolve from a fixed star to that star again in exactly the same time, just as if the Earth had a diurnal motion only, and remained always in the same part of its orbit.

But with respect to the Sun, as the Earth advances nearly one degree eastward in its orbit in the same time that it turns eastward on its axis, it must make more than a complete rotation before it can come into the same position with regard to the Sun as it occupied the day before. In the same way, when the hands of a clock set off together at twelve o'clock, the minute hand must travel more than a whole circle before it will overtake the hour hand; that is, before they will be again in the same relative position

Thus, the solar day is longer than the sidereal day by about one 360th part of a sidereal day, or about 4 minutes.



Let S represent the centre of the Sun, and E the Earth moving round the sun in an orbit represented by the circle. Let *m* be a point on the Earth's surface opposite to the Sun. Now the Earth revolves round the Sun and also rotates on its axis. When the Earth has arrived in the position E′, the point *m* has moved to *m′*, which is the exact position which it occupied before with respect to the stars. But it is now in a different position with respect to the Sun, and it has to be carried on by the rotary motion of the Earth to *n*, before it again arrives opposite to the Sun.

Mean Solar Day. Solar days, unlike sidereal days, are not all of the same length. The difference depends on two causes.

1. The Earth does not always move round the Sun with the same velocity. When it is near perihelion it moves faster than when near aphelion, as we have already explained. Hence the space represented by *m′n* is greater at one part of the year than at another, and consequently the difference between the sidereal day and the solar day is a variable quantity.

2. The axis of the Earth not being perpendicular to the plane of its orbit, the plane of the equator does not coincide with that of the ecliptic. Now the Sun's apparent annual motion is not in the equinoctial but in the ecliptic; hence his apparent diurnal motion is not always parallel to the equinoctial. This causes a difference between the corresponding lengths on the two great circles of the heavens. The subject

is too complicated to be dealt with here, and cannot be well understood without the aid of globes.

The average length of a solar day is 24 hours. This is called the **Mean Solar Day**.

Clocks are regulated on the basis of the Mean Solar Day. Sun-dials are dependent on the apparent motion of the Sun itself; hence they exhibit the variations of the solar day as it differs in length at different times in the year. Clocks and sun-dials generally mark somewhat different points of time; they are only together four times in the year—on Dec. 24, April 15, June 15, and Sept. 21.

Equation of Time. Tables have been drawn up marking the difference between Solar time (as shown on the sun-dial) and Mean Solar time (as shown by clocks and watches) at any date in the year. This adjustment of the two systems is called the equation of time.

Month. In the chapter on the Moon we explain the difference between the periodical (or sidereal) month, and the synodical (or lunar) month. These, as will be easily seen, are analogous to the sidereal and solar days.

There is also the **Calendar Month**, which is an arbitrary division of time, by which the year is divided into 12 unequal portions called Months, and named January, February, etc.

Year. The division of time into years is based on the revolution of the Earth round the Sun, and the succession of seasons resulting therefrom.

The **Astronomical Year**, or **Equinoctial**, or **Tropical** year is the period of time in which the Earth performs a revolution round the sun. This period is 365 days, 5 hours, 48 minutes, 49·7 seconds.

The **Calendar Year**, or **Common Year**, consists of 365 days. This is less than the true year by nearly six hours.

The true period of the Earth's revolution was unknown in ancient times. Julius Cæsar fixed the length of the year at 365 days, 6 hours. In order to arrange for the six additional hours in each year, he introduced an extra day every fourth year. Thus, each fourth year, or Leap Year, was made to consist of 366 days. From him it was called the Julian Year.

The Romans inserted the extra or intercalary day between the 24th and 25th of February. In their calendar, the 24th of February was called sextum calendas Martias (being their 6th day of March), or the 6th of the Calends of March; hence the intercalated day was termed *bis sextum calendas Martias*, or the *second* sixth of the calends of March, and thus the year of intercalation received the name of **Bissextile**, which it has retained ever since.

Bissextile, or **Leap Year**, may be known by dividing the date of the year by 4; if there be no remainder, it is Leap Year. If there be any remainder, it is not Leap Year. The remainder indicates the number of the year after the previous Leap Year.

The addition of the extra day did not effect a perfect adjustment of the year to the actual period of the earth's revolution. It occasioned an error of about 11 minutes and 11 seconds every year, or of a whole day in about 130 years. Nevertheless, the Julian year continued in general use till 1582, when Pope Gregory XIII. undertook to rectify the error, which by that time amounted to 10 days. He commanded the ten days between the 4th and 15th of October, 1582, to be suppressed, so that the 5th day of that month was called the 15th. This alteration was accepted through the greater part of Europe, and the regulated method of computation was called the **Gregorian Year**, or **New Style**. It was not admitted into our calendars till 1752, when the error amounted to nearly 11 days, which were taken from the month of September by calling the 3rd of that month the 14th. The change was not effected in England without much senseless opposition.

According to the present arrangement, the years 1800 and 1900 are reckoned as common years, having only 365 days in each; and every four hundredth year afterwards will be a common year also. By this mode of reckoning the remaining error will not amount to a single day in less than 5,000 years.

In England, the beginning of the year was changed from the

25th of March to 1st of January. Thus the succeeding months of January, February, and March, up to the 24th, which would, by the Old Style, have been reckoned part of the year 1752, were accounted as the first three months of 1753. Hence we sometimes see such a date as Feb. 10th, 1774–5, that is, according to the Old Style it was 1774, but according to the New Style it is 1775, because now the year begins at a different date.

III. THE MOON.

The Moon is a satellite (Lat., *satelles*, a life-guard) or attendant of the earth, round which she revolves in the period of a month. She shines, not by her own light, but by light thrown on her from the Sun and reflected.

Size. The diameter of the moon is about 2,160 miles. Her apparent diameter varies from $28\frac{3}{4}'$ to $33\frac{1}{2}'$. She appears largest when on the meridian of any place, and smallest when near the horizon, being about 3,000 miles nearer to an observer at the former position than at the latter. The diameter of the Moon is about one-fourth of that of the Earth; her bulk about one-forty-ninth; and her mass about one-eighty-eighth (the density of the Moon being less than that of the Earth).

Distance from the Earth. The mean distance of the Moon from the Earth is about 238,000 miles; but as she revolves round the Earth in an elliptical orbit, there is a difference of about 50,000 miles between her greatest and least distances from us.

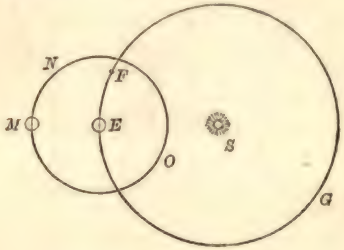
Rotation. The Moon rotates on her axis in precisely the same period that she takes to perform one revolution round the Earth, 27 d. 7 h. 43 m. Hence she always presents the same hemisphere towards us. We never see the other side of the Moon.

Revolution. The exact time in which the Moon performs one revolution round the Earth is, as we have already stated, 27 d. 7 h. 43 m. This is called the **Periodical Month**; it is the time in which the moon revolves from one point of the heavens to the same point again. If, however, we observe the

length of time which elapses between one New Moon and the next, we find it to be 29 d. 12 h. 44 m. This is called the **Synodical Month.**

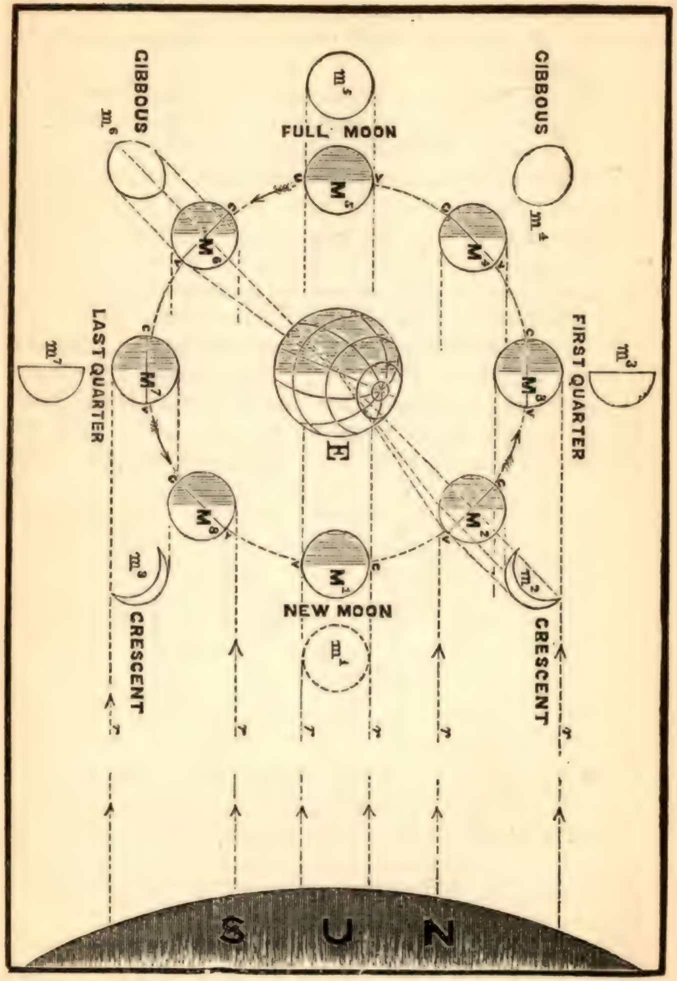
The difference between the two periods is occasioned by the earth's annual motion in its orbit. It may be illustrated by the hands of a watch. They are together at 12 o'clock; but at the end of an hour, though the minute hand has completed a revolution, and arrived at the point whence it started, it does not again coincide with the hour hand. For during this time the latter has advanced the twelfth part of its revolution; and the minute hand, in order to overtake it, has to travel during an additional period of somewhat more than five minutes.

Now, applying this to the Earth and the Moon; suppose S to be the Sun, E the Earth (revolving in its orbit E F G), and M the Moon (revolving in her orbit M N O). If the Earth had no motion, the Moon would move round its orbit into the position M again in 27 d. 7 h. 43 m., and then the Moon,



the Earth, and the Sun would be again in the same relative positions as before. But while the Moon is performing her revolution, the Earth has passed through a twelfth part of its orbit, and has arrived at F, attended by its satellite, which has now to describe a further distance before the three bodies can again be in a line.

Phases. If the Moon were a luminous body, she would always shine with a full orb, like the Sun. But as she only shines by light borrowed from the Sun, one-half of her surface



is always dark, and one-half light, like that of the Earth. We generally see only a portion of the illuminated surface of the Moon, which presents to us a variety of appearances, or phases, according to the position she is in with respect to the Earth and the Sun.

The Sun always enlightens one-half of the Moon, M ; and its whole enlightened hemisphere, or a part of it, or none at all, is seen by us, according to her different positions in her orbit with respect to the Earth, for only those parts of the enlightened half of the moon are visible on the earth, which are cut off by, and lie within, the orbit.

When the Moon is at M^1, no part of its enlightened side is visible to the Earth, since it is all turned away from us and towards the Sun. It is then the time of **New Moon**, when, the Moon being in a line between the Sun and the Earth, they are said to be in *conjunction*.

When the Moon has travelled to M^2, a small part of her illuminated hemisphere is within her orbit, and to a spectator on the Earth's surface she appears in the form of a **crescent**, with two horns ; hence she is said to be horned. At M^3 one-half of the enlightened hemisphere is visible, and the Moon is said to be in **Quadrature.** At M^4 three-fourths of the enlightened part is visible to the Earth, and the Moon is then said to be **Gibbous.**

At M^5 the whole of the enlightened face of the Moon is turned towards the Earth. This is at the time of **Full Moon**, when, the Earth being between the Sun and Moon, they are said to be in *opposition*.

In travelling from M^5, through M^6, M^7, and M^8, to M^1, the Moon exhibits the same phases in reverse order, gradually changing from Full Moon to New Moon ; that is, to no visible Moon at all.

The horns of the Moon before conjunction, or New Moon, are turned to the west ; after conjunction, they are turned to the east. They are always turned from the Sun.

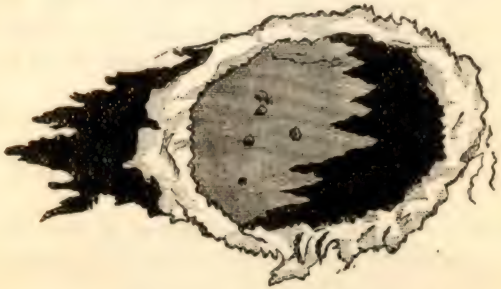
As the length of a day and night on the surface of the Moon

is equal to more than twenty-nine of ours, the Moon has only about twelve days and one-third in the space of one of our years.

The hemisphere of the Moon which is turned towards the Earth is never in darkness, for any portion of it which is turned away from the Sun is illuminated by light reflected on it from the Earth. As the Moon shines on the Earth, so the Earth shines on the Moon. To an observer on the surface of the Moon the Earth presents all the same phases which the Moon does to us, changing from new to crescent, full, and gibbous states. To an inhabitant of the Moon the Earth would appear about thirteen times as large as the Moon appears to us. When it is New Moon to us, it would be Full Earth to him, and *vice versa.*

When the Moon appears as a narrow crescent, we sometimes see the other part of her disc shining with a faint light. This light is caused by the Earth shining on the dark hemisphere of the Moon ; it is in reality Earth-shine.

Physical Features. By means of powerful telescopes, the surface of the Moon has been observed with considerable accuracy. She appears to have either no atmosphere at all, or one of extreme rarity. No signs of clouds, of water, of cultivation, of dwellings, or of living beings, have been found. The surface



A LUNAR MOUNTAIN, WITH ITS SHADOWS.

of the Moon appears to be one unbroken scene of desolation. Vast craters of extinct volcanoes form one of the most remarkable features. One of these, which has been named Copernicus, is said to measure in depth from the top of the wall more than 11,000 feet, while the wall itself rises about half a mile above the ordinary surface of the Moon. This vast crater measures about forty miles across, and it is surrounded by many others of smaller dimensions. No active volcano has been discovered in the Moon.

Lunar mountains and mountain-chains are of huge dimensions. Some of them have been measured by means of the shadows which they cast on the surface of the Moon. A mountain called Dörfell is said to attain a height of more than 26,500 feet. As the Moon is much smaller than the Earth, this is a much greater elevation than any on the surface of our planet, in proportion to the sizes of the two bodies. Thirty-nine mountains higher than Mont Blanc have been measured on the surface of the Moon. This is on only one hemisphere, for it should be remembered that one-half of the Moon is never seen by the eyes of a terrestrial observer.

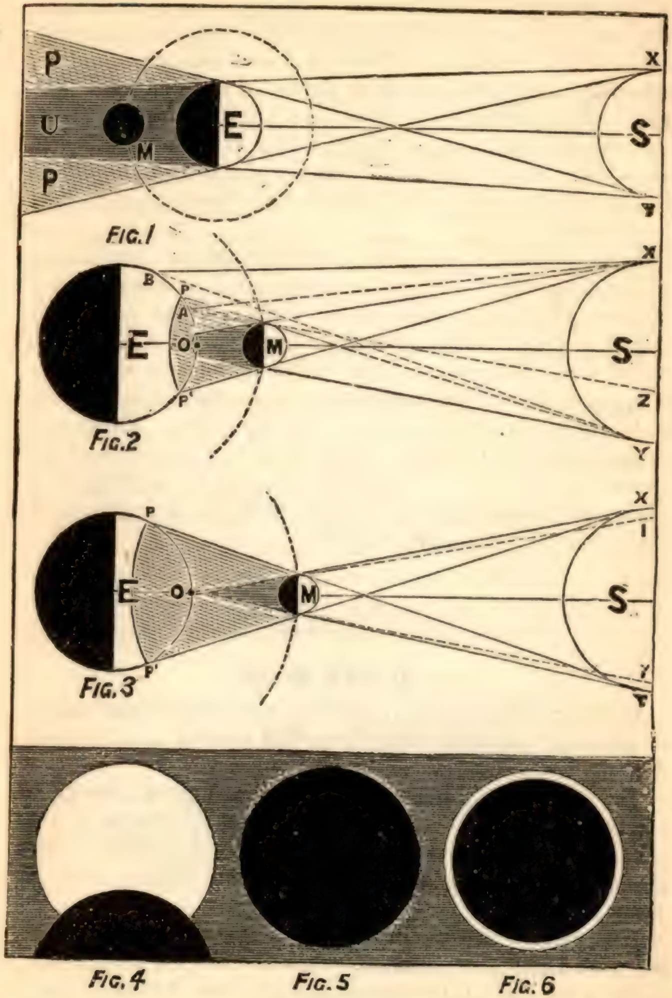
IV. ECLIPSES.

A. OF THE MOON.

When an opaque body is exposed to the light of the sun, or of any other luminous centre, it casts a shadow in a direction opposite to that from which the light proceeds.

The Earth, being a body of this kind, casts a very large shadow in the direction opposite to the Sun. Whenever the Moon, in its revolution round the Earth, passes through this shadow, its disc becomes darkened, and it is said to be in Eclipse.

It is evident that an Eclipse of the Moon can only happen when the Earth is exactly between the Sun and the Moon ; that is, when the Moon is in opposition, at the time of Full Moon.



ECLIPSES.

In the diagram (fig. 1, p. 46) S represents the Sun, E the Earth. The dark frustrum of a cone represents the shadow of the Earth. When the Moon arrives at M, at the time of Full Moon, if it passes through this conical shadow it suffers eclipse.

At first sight it would appear that the Moon would be eclipsed every month at the time of Full Moon. But the plane of the Moon's orbit does not coincide with that of the Earth, but is inclined to it at an angle of rather more than 5°. Hence, unless the Full Moon happens in or near one of the two Nodes, or points in which the two orbits intersect each other, she will pass above or below the shadow of the Earth, in either of which cases there will be no eclipse.

When the Moon's disc is entirely immersed in the shadow of the Earth, the eclipse is total; when only a portion of the Moon's surface passes through the shadow, the eclipse is only partial.

If the Moon when at the full be more than 12° from the node, there can be no eclipse; when she is within that distance, there will be a **partial** or **total eclipse,** according as a part or the whole of her disc falls within the Earth's shadow. If the eclipse happen when the Moon is exactly in the node, it is called a **central eclipse.**

The duration of an eclipse coincides with the time in which the Moon passes through the conical shadow of the Earth. The shadow of the Earth, where the Moon passes through it, is much wider than the diameter of the Moon, and therefore a lunar eclipse lasts sometimes for three, four, or even five hours. The duration of a total or partial eclipse of the Moon varies with her distance from the earth. According as the Moon is nearer to or farther from the Earth, the eclipse will be of greater or less duration, since the shadow, being conical, becomes more and more narrow as it recedes from the Earth.

It will be observed that outside the dark conical shadow marked U there is a lighter shadow in which the sun's light is only partially intercepted. The latter is marked P in the diagram. The darker shadow is called the **Umbra,** and the lighter

the **Penumbra.** When an eclipse takes place, the Moon first enters the Penumbra, then passes through the Umbra, and, after traversing the Penumbra on the other side, finally emerges into the sunlight. The total eclipse of the moon continues only as long as the latter is completely immersed in the Umbra.

Astronomers, knowing the exact distances of the Sun and

A PARTIAL ECLIPSE OF THE MOON, AS SEEN THROUGH A TELESCOPE.

Moon from the Earth at any given time, the size and shape of each of these bodies, and the movements of the Earth and the Moon, are able to calculate the times and conditions of lunar eclipses with the greatest accuracy for any number of years in advance.

B. OF THE SUN.

An eclipse of the Sun is caused by the Moon passing between the Sun and the Earth, and thus intercepting the light coming to us from the centre of the Solar System.

An eclipse of the Sun can happen only at the time of New Moon, when the latter is in conjunction, the Moon being between the Earth and the Sun.

For reasons already explained, an eclipse of the Sun can only take place when the Moon is on or near one of the nodes. When New Moon happens in other parts of her orbit, she passes either above or below the disc of the Sun, and therefore does not intercept any of the solar light coming to us.

Let S (figure 2, p. 46) be the Sun, E the Earth, and M the Moon, at the time of conjunction. The conical shadow of the Moon falls upon the Earth over a space at O. To a spectator situated within this space the whole of the Sun's disc will be obscured; and to him the eclipse will be total. To an observer placed between P and P′, but outside the dark space at O, only a part of the Sun's disc will be obscured; and to him the eclipse will be partial. Observers further north than P, or further south than P′, would see no eclipse at all.

In the above diagram we have supposed the Moon to be at her least distance from the Earth. In this position the point, or apex, of the cone would extend further than the surface of the Earth, if it were not intercepted by the substance of our globe. Thus, a part of the surface of the Earth, lying within the dark cone, is completely obscured, and the eclipse is total throughout this darkened circle. A total eclipse of the Sun is represented in figure 5, and a partial eclipse in figure 4, p. 46.

In figure 3, p. 46, we suppose the Moon to be at her greatest distance from the Earth at the time of the eclipse. The apex of the conical shadow lies between the Moon and the Earth, and does not quite touch the latter. To an observer at O there will be an Annular Eclipse, in which a ring of light appears round the moon, as in figure 6. To an observer north or south of O, but between P and P′, the eclipse will be partial. Further north than P, and further south than P′, there will be no eclipse at all.

A total or annular eclipse of the Sun at any particular place is a very rare occurrence. Either of these phenomena is

visible over only a very small portion of the earth's surface, and only for a very few minutes at a time.

V. THE PLANETS.

The Solar System consists of the Sun, which occupies the centre, a number of planets which revolve round it, various satellites or minor bodies which revolve round the planets, and comets.

The term Planet is derived from the Greek word *planetes*, a wanderer. Planets were so called from their appearing to wander about among the fixed stars, and not keeping the same relative positions with respect to each other and to the other heavenly bodies.

The number of planets known to us is eight; namely, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, besides the asteroids or planetoids, small planetary bodies having their orbits between those of Mars and Jupiter. Only six of these, namely, Mercury, Venus, the Earth, Mars, Jupiter, and Saturn were known to the ancients, and even the Earth was not recognised by them as a planet. Uranus, Neptune, and the Asteroids have been discovered since the invention of the telescope.

Each planet moves round the Sun in an elliptical orbit. The following diagram represents the planets and their orbits in the order in which they are situated with regard to proximity to the Sun.

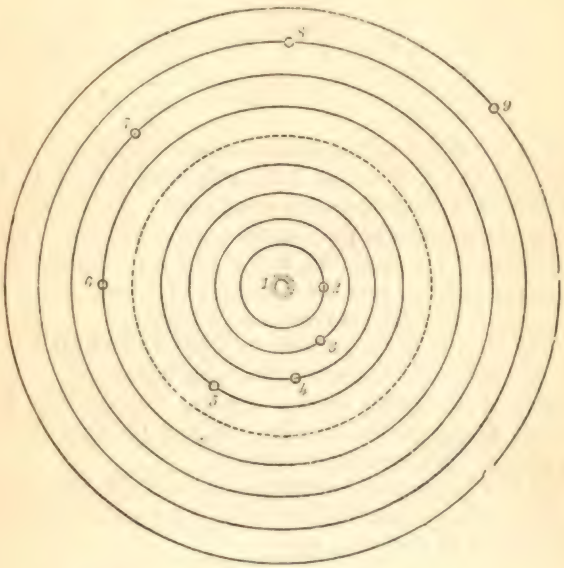
The planets Mercury and Venus, whose orbits are within that of the Earth, are called **inferior planets.**

The planets Mars, Jupiter, Saturn, Uranus, and Neptune, whose orbits lie outside that of the Earth, are called **superior planets.**

The orbits of the planets are all ellipses of various degrees of eccentricity. As a rule, the orbits of the smaller planets are more eccentric than those of the larger ones.

The plane of the equator of each planet, like that of the

Earth, is inclined to the plane of its orbit at a greater or less angle. This angle varies from $3^\circ\ 4'$ in the case of Jupiter to $100^\circ\ 20'$ in that of Uranus. Thus the variation of the seasons is widely different in the various planets.



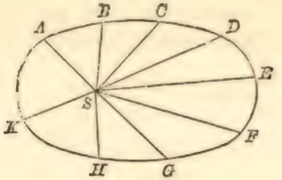
1. The Sun.	4. The Earth.	7. Saturn.
2. Mercury.	5. Mars.	8. Uranus.
3. Venus.	6. Jupiter.	9. Neptune.

The dotted line circle denotes the position of the Planetoids.

KEPLER'S LAWS.—The famous German astronomer, Kepler, who lived in the 16th and 17th centuries, discovered three laws relating to the motions of the planets and their distances from the Sun. They are as follows:—

1. The path or orbit of each planet is an ellipse, of which the Sun occupies one of the foci.

2. Equal areas of the ellipse are described in equal times



Let A B C D E F G H K represent the elliptical orbit of any planet, and let the distances A B, B C, C D, D E, E F, F G, G H, H K, K A, be described in equal times. Then if the point S represent the centre of the Sun, the areas A S B, B S C, C S D, D S E, E S F, F S G, G S H, H S K, K S A are equal. Thus, though the *distances* vary, since the planet travels faster as it gets nearer to the sun, yet the *areas* are equal.

3. The squares of the periodic times are to each other in the same proportion as the cubes of the mean distances.

This is a remarkable relation existing between the mean distances of the planets from the Sun, and the times in which they perform their revolutions round it.

Thus, if P be the period of one planet (the Earth, for example), and D its distance from the Sun ; also p the period of another planet, and d its distance ; then—

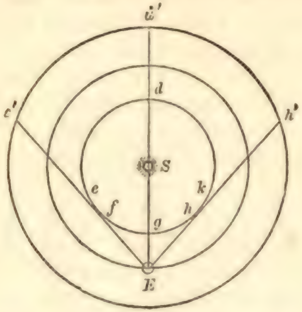
$$P^2 : p^2 :: D^3 : d^3$$

By means of this proportion, if we know three terms we can find the other. Thus, knowing the period of the Earth and its mean distance from the Sun, if we also know the period or the distance of another planet, we can find its distance or period.

Our readers can easily verify this law by applying it to the actual numbers which we shall give when we come to treat of the different planets.

APPARENT MOTION. Though the planets always travel in the same direction round the Sun, when viewed from the

Earth their courses seem very irregular. Sometimes a plane appears to travel with a direct motion, then it seems to remain stationary, and at another time its apparent motion is retrograde. The reason of this will appear from the following diagrams :—



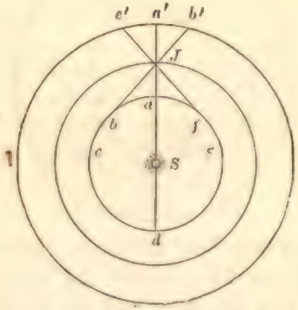
Let S represent the Sun, the inner circle the orbit of an inferior planet, Venus for example, the middle one the orbit of the Earth (E), and the outer one the circle of the heavens. As Venus passes from *d* to *e*, she will appear, to an observer on the earth, to move in a direct motion along the sky from *d'* to *e'* ; then for a short time as she travels from *e* to *f* she will appear stationary, or nearly so, till she arrives at *f*. As she moves from *f* to *g*, she will appear to travel with a retrograde motion from *e'* back to *d'*. Similarly, as she passes from *g* to *h*, her apparent motion will be from *d'* to *h'* ; then, as she moves from *h* to *k* she will appear stationary at *h'* ; and lastly, as she journeys from *k* to *d*, she will seem to travel once more with a direct motion from *h'* to *d'*.

Thus, during an entire revolution round the Sun, her motion will appear (1) direct, from *d'* to *e'*, (2) stationary, at *e'*, (3) retrograde, from *e'* to *d'*, (4) still retrograde, from *d'* to *h'*, (5) stationary, at *h'*, and (6) again direct, from *h'* to *d'*.

We have here supposed the Earth to be stationary, but it is evident that the apparent motion of the inferior planet will be still further complicated by the actual motion of the Earth.

Next, let the inner circle represent the orbit of the Earth, and the middle one the orbit of a superior planet, as Jupiter.

As the Earth makes a revolution in a much shorter time than Jupiter, it is evident that the apparent motion of the latter will depend mostly on the actual motion of the Earth. We will therefore now suppose Jupiter to remain stationary at J, while the Earth moves in its orbit.



As the Earth passes from *a* to *b*, Jupiter will appear, to a terrestrial observer, to move with a direct motion along the sky from *a'* to *b'*; then, as the Earth travels from *b* to *c*, Jupiter will appear stationary, or nearly so, at *b'*. As the Earth moves from *c* to *d*, Jupiter's apparent motion will be retrograde from *b'* back to *a'*. Similarly, as the Earth passes from *d* to *e*, Jupiter's apparent motion will still be retrograde from *a'* to *e'*; then, as the Earth moves from *e* to *f*, Jupiter will appear stationary at *e'*; and lastly, as the Earth journeys from *f* to *a*, Jupiter will be seen to travel once more with a direct motion from *e'* to *a'*.

It is evident that the apparent motion of Jupiter will be still further complicated by the actual motion of Jupiter himself in his revolution round the Sun.

MERCURY. This is the planet which has the smallest orbit, and is nearest to the Sun. Its mean distance from the Sun is about 35,400,000 miles, and it performs its revolution round the

Sun in a period of nearly 88 days, at the average rate of about 100,000 miles per hour.

It is the smallest of the planets, with the exception of the asteroids, or planetoids, its diameter being only 2,962 miles at the equator. Hence it is about three times the size of our Moon.

As Mercury is never distant more than 30° east or west from the Sun, and is never above the horizon more than two hours either before or after the Sun, this planet is not often visible, and a favourable opportunity for observing him seldom arises. He may sometimes be seen through a telescope during the daytime.

The apparent diameter of Mercury varies according to his distance from the Earth. When nearest the Earth, at the inferior conjunction, it is about 12″, and when furthest from the Earth, at the superior conjunction, it is about 5″.

Mercury sometimes passes exactly between the Earth and the Sun, appearing to travel across the sun's disc. This is a **Transit of Mercury,** when the planet appears as a dark spot on the Sun's surface.

This planet does not always present the same appearance when seen through a telescope. It exhibits *phases* similar to those of the Moon, sometimes appearing like the new Moon, sometimes like a half Moon, and sometimes like the full Moon. These changes arise, as in the case of the Moon, from the fact that at different times a smaller or larger portion of the illuminated surface of the planet is turned towards us.

Mercury appears to shine with a brilliant white light. No spots have been accurately observed on his surface, though one German astronomer has professed to find traces of continents and oceans. The planet is believed to have a dense atmosphere, which moderates the scorching rays of the Sun shining upon it at such a comparatively short distance. It has no moons.

Mercury is remarkable for the great eccentricity or elongation of its orbit, exceeding that of any other planet. From this cause

it follows that the difference between his greatest and least distance from the Sun is more than 14 millions of miles, or about $\frac{2}{8}$ of the mean distance. In the case of the Earth the difference is only about 3 millions of miles, or less than $\frac{1}{30}$ of the mean distance from the Sun.

VENUS. This is the planet whose orbit is nearest to that of the Earth. Like Mercury, she never appears at a very great distance from the position of the Sun, though she recedes somewhat farther from it than that planet. She is, next to the Sun and Moon, the most brilliant and striking of all the heavenly bodies, sometimes appearing before the Sun as the Morning Star (Lucifer), and at other times after the Sun as the Evening Star (Hesperus). So great is the splendour of this planet's light, that it is capable of casting a shadow of a body on the Earth, and, under favourable circumstances, she may be seen shining in the sky in broad daylight.

The mean distance of Venus from the Sun is rather more than 66 millions of miles. Her orbit is nearly circular, hence the difference between her greatest and least distances from the Sun is comparatively small, less than a million miles. She completes her revolution round the Sun in a period of 224 days 17 hours, at an average rate of about 80,000 miles per hour.

The diameter of Venus at the Equator is about 7,500 miles, being somewhat less than that of the Earth.

At the period of inferior conjunction, Venus is distant from us about 23 millions of miles; and at the period of superior conjunction, nearly 160 millions of miles.

When viewed through a telescope, this planet exhibits phases like those of the Moon. At the period of her greatest brilliancy she appears as a beautiful crescent when observed by the aid of a glass.

The great splendour of Venus, casting a dazzling and almost blinding light over her surface, renders her a difficult subject for telescopic observation. Hence, though she is so near to the Earth, little is known of her. Dusky spots appear on her surface, but they are supposed to belong, not to the planet herself,

but to the surrounding atmosphere. Some astronomers assert that they have discovered mountains more than 20 miles in height near the horns of the crescent. Observations of the movement of spots on the surface of the planet have led to the supposition that she revolves on her axis in a period of between 23 and 24 hours.

The **Transits of Venus** are of vast astronomical importance, as affording a means of ascertaining the distance of the Sun from the Earth, and from thence of calculating the distance of other heavenly bodies. They are of very rare occurrence; only one or two happen in the course of a century. The following are a few of the dates of former and future successive transits:—1761, 1769, 1874, 1882, 2004.

Like Mercury, Venus has no satellite.

THE EARTH. As our own planet has been fully described elsewhere, it will be sufficient here to give briefly a few of the leading astronomical facts relating to it.

The Earth is the third planet from the Sun, taken in order of distance.

Its mean distance from the Sun is nearly 91,500,000 miles. The difference between its greatest and least distances from the Sun is rather more than three millions of miles. The Earth is in aphelion on the 21st of June, and in perihelion on the 22nd of December, so that it is actually more than three millions of miles nearer to the Sun in the middle of our winter than in the middle of our summer.

The Earth's diameter at the equator is 7,925 miles; at the poles 7,901 miles: mean diameter, 7,912 miles. It revolves on its axis in a period of 23 hours 56 minutes 4 seconds.

The Earth travels round the Sun in a period of 365·2563 days. Its equator is inclined to the ecliptic at an angle of about 23½ degrees.

The Earth has one satellite, the Moon, which revolves round it once in every 27 days 7 hours 43 minutes.

MARS. This is the fourth of the planets, and the first of the superior planets. He derives his name (that of the god

of war) from his fiery, red appearance, which has been ascribed to a dense atmosphere by which he is said to be surrounded. Recent observations have, however, tended to throw doubts on this theory. When viewed through a telescope, his surface is seen to be covered with spots irregular in shape and dusky in colour. These are supposed to indicate the outlines of continents and oceans. Near the poles there are two white spots, which seem to be caused by the presence of large masses of snow, as each becomes sensibly smaller according as each pole is turned towards the Sun. When nearest the Earth, he appears nearly as large as the planet Jupiter.

The mean distance of Mars from the Sun is nearly 140 millions of miles. The eccentricity of its orbit causes a difference of about 26 millions of miles between the distances from the Sun at aphelion and at perihelion. He performs a revolution round the Sun in a period of nearly 687 days. Hence his year is nearly twice as long as one of ours.

The diameter of Mars at the equator is about 4,920 miles. He is thus considerably smaller than the Earth, and than Venus, but much larger than Mercury.

As Mars is many millions of miles nearer to us at one time than at another, his apparent size varies considerably. His diameter appears about seven times as great when he is nearest to us than when he is furthest from us.

When viewed through a telescope, Mars exhibits phases like those of the Moon, but they are not so clearly defined as those of Venus.

The **ASTEROIDS**, or **PLANETOIDS**, as they are perhaps more correctly called, are a number of small planetary bodies revolving round the Sun in orbits situated between those of Mars and Jupiter. They may be regarded as invisible to the naked eye, though it is said that two of them, Ceres and Vesta, may be sometimes indistinctly seen without the aid of a glass.

The discovery of the Asteroids was mainly caused by the influence of **Bode's Law** on the minds of astronomers at the

commencement of this century. Professor Bode, of Berlin, had called the attention of scientific men to a curious relation existing between the distances of the planets from the Sun. This relation is expressed by a series of numbers, and is called Bode's Law, though he was not the original discoverer of it. Take the numbers 0, 3, 6, 12, 24, 48, 96, 192, forming a series in which each number after the second is obtained by doubling that which precedes it. If we now add 4 to each number, we obtain the following series :—

4, 7, 10, 16, 28, 52, 100, 196.

The numbers in this series represent with considerable accuracy the *relative distances* of the planets from the Sun. Thus, if 4 represent the distance of Mercury, then

7	will represent	the distance of	Venus,
10	"	"	the Earth,
16	"	"	Mars,
.	.	.	.
52	"	"	Jupiter.
100	"	"	Saturn.
196	"	"	Uranus.

It will be observed that we have no planet represented by the number 28, so that a gap occurs in the series which seems to require filling up. At the commencement of the present century, astronomers were not aware of the existence of any planetary body between the orbits of Mars and Jupiter. Bode, however, insisted on the probability of another planet existing between these bodies and corresponding to the number 28 in the series. His remarks so impressed several observers of the time, that they began to search for the required planet; and in 1801, on the very first day of the year and of the century, *Ceres*, the first asteroid, was discovered by Piazzi at Palermo, in Sicily. *Pallas* was discovered by Olbers in 1802, *Juno* by Harding in 1804, and *Vesta* by Olbers in 1807. Then were discovered *Astræa*, *Hebe*, *Iris*, *Flora*, *Metis*, *Hygeia*, *Parthenope*, and *Victoria* (the

last in 1850). New asteroids are discovered almost every year, and their number now amounts to two hundred and fifty-two.

These bodies vary in size, but they are all very small compared with the other planets. Their magnitudes have not been ascertained with accuracy, but the largest is not more than 228 miles in diameter, while some have a diameter of only a few miles.

Their orbits lie generally nearer to that of Mars than to that of Jupiter. The nearest to the Sun is Flora, which has a mean distance of 201 millions of miles, and revolves round the Sun in 3¼ years. The farthest is Maximiliana, which has a mean distance of 313 millions of miles, and performs a revolution in about 6½ years.

Some of them revolve in orbits with great eccentricity; and in some cases their orbits are inclined to the ecliptic at a large angle. For example, the orbit of Pallas is inclined to the ecliptic at an angle of about 34½ degrees.

It has been conjectured, with much appearance of probability, that each of these small bodies once formed part of one large planet which formerly revolved in its orbit at the distance represented by the number 28 in Bode's series, and which may have been broken into fragments through collision with another planet or from some other unknown cause.

JUPITER. This is by far the largest of the planets, and, with the exception of Venus, the most brilliant as seen from the Earth. He is named Jupiter, after the name of the King of the ancient gods, on account of his immense size and majestic appearance in the heavens. Like Venus, he is a Morning Star when seen before sunrise, and an Evening Star when seen after sunset.

The mean distance of Jupiter from the Sun is nearly 476 millions of miles. The eccentricity of his orbit is represented by a difference of nearly 46 millions of miles between his greatest and least distances from the Sun. He revolves round the Sun in a period of about 4,332½ days; hence his year is nearly twelve times as long as ours.

The equatorial diameter of Jupiter is rather more than 85,000 miles. He revolves on his axis in the space of nearly ten hours; hence his diurnal revolution must be performed with amazing velocity, his day being shorter and his circumference greater than that of any other planet. The equator of the planet is inclined to the plane of the orbit at an angle of only a little more than 3 degrees. From these data we learn that the night and day of Jupiter are each on an average only five hours long, that they are nearly equal all the year round, and that there is very little change of seasons on the surface of the planet.

When viewed through a telescope, the surface of this planet appears marked with belts of a dark colour, and running generally parallel to the equator. As they vary in position and shape, they are supposed to be caused by the dense atmosphere of the planet, as affected by winds blowing over its surface.

Jupiter is attended by four moons or satellites, which revolve round it from west to east. They are invisible to the naked eye, and are said to have been discovered by the eminent astronomer Galileo, soon after the invention of the telescope in the early part of the 17th century.

The first satellite (Io) revolves round Jupiter in 1 day 18 hr., at a mean distance of nearly 270,000 miles, and has a diameter of about 2,250 miles. The second (Europa) completes its revolution in 3 days 13 hours, at a mean distance of about 425,000 miles, and has a diameter of about 2,100 miles. The third (Ganymede) performs its revolution in nearly 7 days 4 hours, at a mean distance of about 678,000 miles, and has a diameter of rather more than 3,400 miles. The fourth (Callisto) revolves round Jupiter in 16 days 16½ hours, at a distance of nearly 1,200,000 miles, and has a diameter of rather more than 2,900 miles. It will be seen that these satellites all travel much more swiftly than our Moon, completing far greater revolutions in a much shorter space of time. We also notice that they are of considerable size. The smallest is not quite so large as our Moon, while the two largest are greater than the planet Mercury.

As seen through a telescope, the positions of the satellites with regard to the planet vary greatly. Sometimes all four are seen on the same side of Jupiter, sometimes two are on one side and two on the other. At other times one or more are hidden behind the body of the planet, and on very rare occasions not a single satellite has been visible.

It has been ascertained that, as in the case of our Moon, all the satellites of Jupiter revolve on their axes in exactly the same time as they require to complete one revolution round the planet. Each satellite, therefore, always presents the same half of its surface towards Jupiter, the other side being always turned away from the planet.

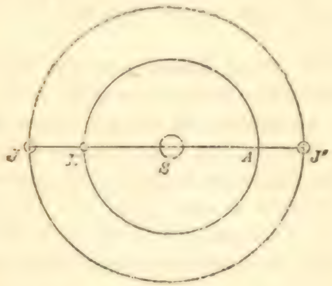
As the satellites of Jupiter are very small compared with the vast bulk of the planet round which they turn, each one of them suffers an eclipse every time that it arrives in that part of its orbit furthest removed from the Sun, since it is then in the shadow of the great planet. Thus the eclipses of Jupiter's satellites occur with great regularity, and being clearly visible to us through a good telescope, they can be calculated for any number of years in advance with the greatest accuracy. The first satellite having a comparatively small orbit, and completing each revolution in a short period, suffers very frequent eclipses, and observations taken in connection with them can be renewed at very short intervals, and are of the utmost value.

The times of the eclipses of Jupiter's satellites are published in a scientific publication called the *Nautical Almanac*, a work indispensable to navigators, and published several years in advance, for the convenience of seamen proceeding on long voyages, and of astronomers engaged in calculations which require information with regard to the position of stars, planets, etc., for some years beforehand.

By means of the eclipses of Jupiter's satellites, longitude may be ascertained by navigators out at sea. This is done in the following manner. The time of each eclipse is accurately set down in the *Nautical Almanac*, reckoning by Greenwich time. Now an observer on any part of the Earth's surface, by remarking

the moment at which a certain eclipse commences or ends, and referring to the almanac, knows the exact Greenwich time at that particular instant. By observing at what moment the Sun reaches the meridian altitude (noon), he is also able to ascertain the time at the particular spot in which he happens to be. A comparison of the two times will give him the longitude. For since the Sun appears to travel from east to west round the Earth in twenty-four hours, he seems to pass over one twenty-fourth part of the Earth's surface, or 15 degrees, during each hour. Thus noon arrives one hour later on the surface of the Earth for each interval of 15° to the west, and *vice versâ*. Hence if the observer finds that his time is two hours later than Greenwich time, he knows that his longitude is 30° W. If, on the other hand, his observations show that his time is three hours before Greenwich time, he knows that his longitude is 45° E. This mode of ascertaining longitude was formerly much more employed than at present; it has now been partially superseded by methods which are found more convenient in practice.

Observations of Jupiter's satellites led to the discovery of the rate of speed with which light is transmitted. The Danish astronomer Römer noticed that the eclipses of Jupiter's satellites



sometimes occurred a few minutes earlier, and sometimes a few minutes later, than the calculated times. Careful observations convinced him that these variations depended on the distance

of the planet from the Earth. He found that the eclipses happened nearly 16½ minutes earlier when the Earth and Jupiter were at their least than when they were at their greatest distance from each other. He then came to the conclusion that the 16½ minutes was the time which light required to travel over the space represented by the difference between the greatest and least distances of the Earth and Jupiter from each other. This difference is equal to the diameter of the Earth's orbit, as will appear from the accompanying diagram. The inner circle represents the Earth's orbit, and the outer circle that of Jupiter. S represents the Sun, E the Earth, and J, J′ the planet Jupiter when at his least and greatest distances from the Earth. The difference between these two distances is evidently E A, which is the diameter of the Earth's orbit, about 183 millions of miles. From these data Römer inferred that light travels 183 millions of miles in about 16½ minutes, or at the rate of about 190,000 miles per second. These calculations have been amply verified by more recent observations of other astronomical phenomena.

SATURN. Next in order of distance from the Sun is the planet Saturn, the last of those known to the ancients, and the most remote of those clearly visible to the naked eye. It is frequently seen by night in our sky, and shines with a rather dull, feeble light.

The mean distance of Saturn from the Sun is about 872 millions of miles. The eccentricity of his orbit causes a difference of nearly 98 millions of miles between his greatest and least distances from the Sun. He revolves round the Sun once in about 29½ of our years, at a speed of 22,000 miles per hour.

The size of Saturn is enormous. As his diameter at the equator is nearly 72,000 miles, he is no unworthy rival of Jupiter himself, while he far surpasses every other known planet in magnitude.

The greatest distance from the Earth is about 1,000 millions of miles; while the least distance is about 831 millions of miles.

As he rotates on his axis in the short space of 10 hours 29 minutes, and therefore with enormous velocity, he is much flattened at the poles, like Jupiter.

Dark-coloured belts are observed on the surface of Saturn when seen through a telescope, but they are not so distinct and well-defined as those of Jupiter.

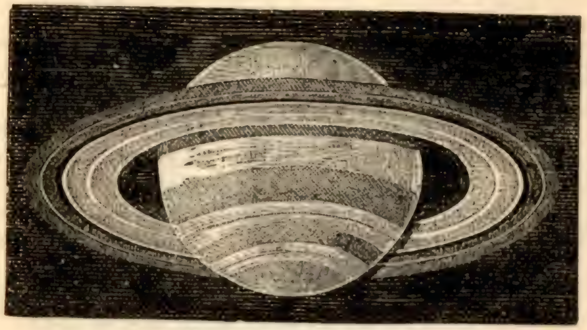
Saturn is accompanied by no less than eight satellites, which revolve round him in various periods of time. The first was discovered in 1789 by Sir W. Herschel, who also discovered another one two years later. Like the satellites of other planets it is supposed that each rotate on its axis in the same time in which it performs a revolution round the superior body.

The following is a table of the moons of Saturn, giving (in round numbers) the size, time of revolution, etc., of each :—

Name of Satellite.	*Distance from Saturn.*	*Time of each Revolution.*			*Diameter.*
	Miles.	d.	h.	m.	
Mimas	121,000		22	37	1,000
Enceladus . . .	155,000	1	8	52	not known
Tethys	190,000	1	21	18	500
Dione	246,000	2	17	41	500
Rhea	343,000	4	12	25	1,200
Titan	796,000	15	22	41	3,300
Hyperion . . .	1,007,000	21	7	8	not known
Japetus	2,314,000	79	7	55	1,800

The distinguishing feature of Saturn, that which makes it the most magnificent of all planetary bodies when seen through a telescope, is the series of rings by which it is surrounded. The true form of these appendages was not discovered at once. The peculiar appearance of Saturn was first observed by Galileo, who came to the conclusion that it was a triple-formed planet, the middle and largest body being attended by two smaller ones—one on each side. About forty years afterwards, when improved telescopes were in use, the Dutch astronomer, Huygens, announced that Saturn was surrounded by a ring which encircled the planet without touching it in any point

Further discoveries have made known to us that what at first appeared to be only one ring is really a system or series of four



SATURN AND ITS RINGS.

or more rings, all in the same plane, but separated from each other by distinct intervals of space. These rings are broad, thin, flat, and opaque, or partly so, as they cast a shadow on the body of the planet. The inner ring is partly transparent, as the surface of Saturn can be seen through it.

The nature of these rings is still a matter of conjecture. Recent observations with telescopes of very high power have seemed to show that the system is composed of a considerable number of rings, one within another, revolving round the planet. Some astronomers now suppose that the rings consist of myriads of tiny satellites, each having an orbit of its own in which it revolves round the planet.

The whole of the rings, taken together, form a complete system, which may in a general way be regarded as a single ring. The distance from the centre of the planet to the outer edge of the ring is about 83,000 miles; to the inner edge 46,000 miles. Hence the entire breadth of the ring is about 37,000 miles. Its thickness seems to be not more than 100 miles.

The rings, like the planet and its satellites, are illuminated by the Sun; and the shadow of Saturn may generally be seen falling upon and darkening that portion of the circle which lies

furthest from the Sun. The use of the rings is probably to assist in giving light to the planet by reflecting the rays of the Sun upon its surface. The system of rings must exhibit a very magnificent appearance as seen from the surface of Saturn at night time.

As seen from the Earth, the system of rings varies in appearance according to the position in which it presents itself to an observer on the surface of our globe. Sometimes it takes the form of an ellipse, more or less elongated according as its plane is more or less inclined towards us. When the edge of the outer ring is directly turned towards the Earth, the system of rings takes the form of a straight line. On rare occasions, when the dark edge of the outer ring is turned towards the Earth, the rings vanish altogether from our view, or appear only as a faint line crossing the disc of Saturn.

URANUS. We now come to planets which have been discovered in modern times, and were entirely unknown to the ancients, who were without the aid of the telescope.

Uranus was discovered in 1781, by Sir William Herschel. It seems to have been previously sighted by other astronomers, but it had always been taken for a star, and to Herschel was reserved the honour of discovering that it is a planet. It can scarcely be said to be visible to the naked eye, though it may be indistinctly seen by persons of strong vision on a very dark and clear night, when it is in that part of its orbit which lies nearest to the Earth.

The mean distance of Uranus from the Sun is nearly 1,754 millions of miles. He revolves round the Sun in a period equal to rather more than 84 of our years.

His diameter is about 33,000 miles.

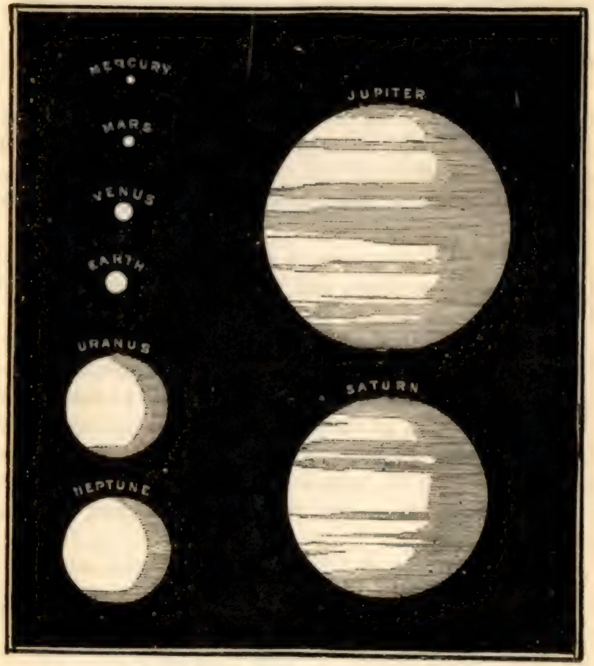
On account of his immense distance from the Earth, little is known of this planet. Neither spots nor belts have been observed on his surface, and the time of rotation on his axis is unknown.

Four satellites of Uranus have been discovered, and have received the names of Ariel, Umbriel, Titania, and Oberon.

This planet has sometimes been called *Herschel*, in honour

of the discoverer, and *Georgium Sidus*, a name given to it by Herschel, after George III. The name Uranus has now, however, generally superseded the others.

NEPTUNE. This planet is specially remarkable for the mode in which it was discovered. It had been observed that



COMPARATIVE SIZES OF THE PLANETS.

the path of Uranus did not exactly correspond with the calculations based on the known conditions of his motion. Two astronomers, M. Leverrier of Paris, and Mr. Adams of Cambridge, instituted independent investigations to account for the discrepancies; and each of them came to the same conclusion,

namely, that they were caused by the attraction of some unknown planet moving outside the orbit of Uranus. They then set to work, by a series of intricate mathematical calculations, to find out the *position* of the body which they supposed to exist. The positions arrived at by the two observers were very nearly identical. Leverrier was the first to give the result of his calculations to the world; and when, in 1846, Dr. Galle of Berlin directed the telescope of the Royal Observatory to that part of the heavens pointed out by the French astronomer, the new planet was almost immediately discovered.

The mean distance of Neptune from the Sun is no less than 2,746 millions of miles.

His equatorial diameter is about 36,500 miles, so that he is rather larger than Uranus.

Nothing is known of his surface, nor of the time of rotation on his axis.

Only one satellite has been discovered, but it is probable that a planet at such a vast distance from the centre of the solar system is provided with more than one moon, to make up for the deficiency of light received directly from the Sun.

TABLE OF THE PLANETS.

(*The numbers are approximate.*)

Name.	*Diameter in miles.*	*Distance from the Sun, in miles.*	*Period of Revolution, in days.*	*Period of Rotation, in hrs. and mins.*	*No. of Satellites.*
Mercury .	2,962	35,400,000	88	24 5	0
Venus . .	7,500	66,000,000	225	23 16	0
Earth . .	7,912	91,500,000	365¼	23 56	1
Mars . .	4,920	140,000,000	687	24 37	0
Asteroids .	—	—	—	—	—
Jupiter . .	85,000	476,000,000	4,332½	9 55	4
Saturn . .	72,000	872,000,000	10,759¼	10 29	8
Uranus. .	33,000	1,754,000,000	30,687	not known	4
Neptune .	36,500	2,746,000,000	60,126¾	not known	1

The Sun's diameter is 852,600 miles.
The Moon's diameter is 2,153 miles.

VI. COMETS.

Besides the planets, there are other less-known members of the solar system, called comets, from the Latin *coma*, a word derived from the Greek, and signifying "hair." A comet is so called from the hairy appearance given to it by the luminous vapoury substance which generally surrounds its densest part, and often extends far away from it in the form of a tail.

It is only in modern times that any reliable information has been gathered with respect to these apparently erratic visitors. The ancients regarded them with wonder and awe, as portending the ruin of kingdoms, famines, pestilences, earthquakes, and other dreadful disasters. This feeling of superstitious awe has descended to times still recent, and still exists among ignorant and uncivilized people even at the present day.

Perhaps the first man of science who gained any real knowledge with regard to comets, was Tycho Brahé, the eminent Danish astronomer, who lived in the sixteenth century. His observations of the comet of 1557 convinced him that that body must be at a greater distance from the Earth than that of the Moon and of some of the planets. These observations and discoveries disposed of all the theories which regarded comets as meteors or vaporous exhalations kindled in the atmosphere and moving about in it like falling stars or *ignes fatui.* Sir Isaac Newton, observing the comet of 1680, was led to the conclusion that it moved round the Sun in an elliptical orbit like those of the planets, having an *aphelion*, or greatest distance from the Sun, and a *perihelion*, or least distance from the Sun.

The following description has been given of the phenomena of a visible comet:—

"A faint luminous circle is discovered by aid of a good telescope; the appearance gradually increases, and after some time a *nucleus* appears, that is, a part in the middle which is more condensed in its light than the rest, sometimes circular, sometimes oval, sometimes even radiated like a star. The appearance

still goes on increasing, the nebula round the nucleus becomes less regular, and a tail begins to form, which looks as if one side of the nucleus were projected in a stream of light away from the body of the comet, which stream grows fainter as it recedes, and finally ceases without any definite boundary. This tail increases in length, so as sometimes to spread across the whole visible heaven; sometimes there are more tails than one, and sometimes the tail seems broken off in parts; it is generally turned away from the Sun, but this rule is by no means universal. The comet approaches the Sun, sometimes in an undulating and irregular curve, sometimes nearly in a straight line; it generally crosses the part of the heaven in which the Sun is found so near to the latter body as to be lost in its rays, but emerges again on the other side, usually with increased brilliancy and length of tail. The phenomena of disappearance are then, in the inverse order, the same as those of its appearance. Frequently it is observed that the dimensions of the comet contract a little as it approaches the Sun and dilate as it recedes again."

Thus there are usually three parts to a fully devoloped comet:—(1) the **nucleus**; (2) the **coma**, or luminous nebula surrounding the nucleus; and (3) the **tail**. The nucleus and coma together are sometimes termed the **head** of the comet. The nucleus is sometimes round, sometimes oval, and sometimes radiated like a star. The nucleus has been found to measure from 30 to 3,000 miles in different comets. Whether it is composed of any solid substance is still a matter of dispute. Some astronomers contend that a comet is wholly gaseous, without any solid matter whatever. It is said that stars have been distinctly seen through the very thickest part of comets. Sir John Herschel says, "Whenever powerful telescopes have been turned on these bodies, they have not failed to dispel the illusion which attributes solidity to that more condensed part of the head which appears to the eye as a nucleus; though it is true that in some a very minute stellar point *has* been seen, indicating the existence of a solid body."

For the ordinary observer the most striking portion of a comet is its tail. Some comets have no tail, others have more than one. The comet of 1743 is said to have had six tails, each more than thirty degrees in length. The tail of a comet is generally turned away from the Sun, but not always. Various theories have been formed to explain the nature of the tail of a comet. It has been said to be fed by the matter raised from the nucleus by the action of the Sun. Newton supposed that it is the result of a continual emission of molecules from the head of the comet. It has been likened to the "tail of smoke emitted by a running locomotive, the outer end being lost in space, and the inner one continually receiving a new supply of molecules." This illustration, however, seems at variance with the fact that the tail goes before a comet when it is receding from the Sun. A correspondent of the *Pall Mall Gazette* says: "There is evidence that the tail is a hollow cone, whose axis is a prolongation of the axis of the nucleus. The nucleus is revolving with one extremity of the axis always directed to the Sun, which exercises a repulsive power on the gaseous matter whirled from the interior of the nucleus."

The question has often arisen, What would be the effect if the Earth came in contact with the tail of a comet? The answer is, that there would most likely be little or no effect at all. The tail of a comet seems to be of such an unsubstantial nature, that the whole of it, though extending for millions of miles through space, may, as one astronomer says, weigh only a few ounces. Indeed, it is highly probable that the earth has more than once passed through the tail of a comet. The well-known astronomer, Mr. Hind, writing to the *Times* newspaper, attributed the phosphorescent appearance of the atmosphere on the night of January 30th, 1861, to the passage of the Earth through the tail of the comet which appeared in that year.

The sizes of comets are of the greatest variety, both with regard to the nucleus, the coma, and the tail. Many of them

have been measured with considerable accuracy. The nuclei are said to vary from about thirty to several thousand miles in diameter, and the tails from nothing to more than a hundred million miles in length. The comet of 1811 was calculated to have had a nucleus 2,600 miles in diameter, and a tail measuring 120,000,000 miles in length, and 15,000,000 miles in breadth.

THE GREAT COMET OF 1811.

With regard to the effect of comets, it has been generally supposed that their presence has caused an increased temperature on the surface of the Earth. The great heat which prevailed during the appearance of the splendid comet of the year 1881 was attributed to the influence of that body. This

opinion, however, seems to be a complete fallacy. During the appearance of the succeeding comet we experienced very cold, wet weather. It is said that the comet of 1680 was also attended by very cold weather.

An influence on the growth of vegetation has also been attributed to comets. The year 1811 was characterized by great heat, a good harvest, and an unusually fine vintage. The excellent wine made in that year was thought to owe its fine qualities to the influence of the comet, and was often called the *comet wine*.

The following years have been remarkable for the appearance of brilliant comets :—

B.C. 371, 134, 43 : A.D. 389, 891, 1106, 1264, 1402, 1456, 1472, 1531, 1556, 1577, 1607, 1618, 1652, 1664, 1655, 1658, 1680, 1744, 1759, 1769, 1807, 1811, 1835, 1843, 1853, 1858, 1881.

Perhaps the finest comet which has appeared during the present century, was that which was visible in 1811, and to which we have already alluded. It came no nearer to the earth than 141,000,000 miles, and yet its tail stretched over a large arc of the evening sky. Many persons believed at the time that it was the same mysterious body which appeared to the wise men at the birth of Christ. James Hogg, the Ettrick shepherd, thus addressed it :—

"Stranger of Heaven ! I bid thee hail !
Shred from the pall of glory riven,
That flashest in celestial gale,
Broad pennon of the King of Heaven !

"Art thou the flag of woe and death,
From angel's ensign-staff unfurled ?
Art thou the standard of His wrath,
Waved o'er a sordid, sinful world?

"No; from that fine pellucid beam,
That erst o'er plains of Bethlehem shone,
No latent evil we can deem,
Bright herald of the eternal throne !

"Whate'er portends thy front of fire,
Thy streaming locks so lovely pale,—
Or peace to man, or judgment dire,
Stranger of Heaven, I bid thee hail."

This comet was calculated to revolve round the Sun in a period of more than 3,000 years ; Bessel assigned to it a perio of 3,383 years.

Halley's Comet is perhaps, from an astronomical point of view, the most famous of all the comets, as it was the first whose appearance was foretold with any degree of accuracy. Following up the discoveries made by Sir Isaac Newton, and carefully comparing the observations made on the comet of 1682 with those recorded of comets which had appeared in former times, he came to the conclusion that it was identical with those which had been seen in 1607, 1531, 1456, 1380, 1305, 1230, and 1155. He therefore ventured to assign to it a period of about seventy-five years, and to predict its reappearance early in the year 1758. His calculations were afterwards rectified by the French astronomers Lalande and Clairaut, aided by Madame Clairaut, who showed that the passage of the comet would be affected by the attraction of Jupiter and Saturn, and that its appearance would take place some months later. Their predictions were verified almost to the letter. The comet was first seen by George Palitzch, a farmer and amateur astronomer living near Dresden, who caught sight of it on Christmas-day, 1758. It reached its perihelion on the 12th March, 1759. This comet appeared again in 1835, arriving at its perihelion in November. Its next visit will take place in 1911. Halley's comet is now regarded as a regular member of the solar system, with a period of between seventy-five and seventy-six years. The greatest distance from the Sun is about 3,000,000,000 of miles, or only a little beyond the orbit of Neptune.

Encke's Comet is another well-known member of the solar system, which has a period of about 1,210 days, and therefore makes frequent returns to our neighbourhood. It was observed by Encke, a German astronomer, in 1818. Having identified it

with the comet seen in 1789, 1795, and 1805, he was able to predict its return in 1822. It was accordingly discovered in that year by Mr. Runker, at Paramatta. Observations on this planet have led Encke and other astronomers to believe in the existence of a resisting medium pervading the space through which the bodies belonging to the solar system have to pass.

When nearest to the Sun it is inside the orbit of Mercury, and when furthest from the Sun it passes between the planetoids and Jupiter. It is said to approach nearer and nearer to the Sun at each revolution.

Biela's Comet was so called after a French astronomer who observed it in 1826, when it is said to have passed within five million miles of the Earth. It was found to have a period of about six years and three-fourths. It appeared again in 1832, 1846, and 1852, and has not been seen since. At its appearance in 1846 it assumed the form of a *double comet*, with two distinct comæ, nuclei, and tails.

During the year 1881 six or seven comets were registered Two of these were distinctly visible to the naked eye in England, and presented a splendid appearance in the evening sky. The largest and most conspicuous was **Tebbutt's Comet**, seen in the northern heavens during the months of June and July. It reached its perihelion on June 16th, when its distance from the Sun was about 67 millions of miles. It made its nearest approach to the Earth five days afterwards, when its distance from us was about 30 millions of miles. According to some observers, its nucleus measured 700 miles in diameter; its coma 200,000 miles in diameter; and its tail 50 millions of miles in length.

WINDS AND CURRENTS.

(1) CURRENTS.

A current (as applied to the ocean) is a stream flowing in a certain direction, and conveying the water from one part of the ocean to another. It is simply a flow of water; an oceanic river. The chief causes of currents are:—

(1) The influence of temperature.

(2) The force of prevailing winds.

(3) The revolution of the earth on its axis.

The water of the ocean near the equator is expanded and made lighter by the heat. Hence, the equilibrium being destroyed, the colder and consequently heavier water from the northern and southern regions flows beneath the water of the tropics. There is, therefore, a general movement of the surface water towards the poles, and of the deeper water towards the equator.

This general flow of the surface water is modified by the action of the winds, which tend to give their own direction to the water exposed to their influence.

Since the earth turns on its axis from west to east, carrying the water with it, this rotatory motion becomes gradually less from the equator to the poles, as the circles of rotation gradually diminish. Hence the water from the equator flowing north and south, acted on by the rotatory motion it received at the equator, arriving at regions where the rotatory motion of the earth is less than its own, *travels faster* to the east than the parts of the earth to which it has flowed. The northerly therefore becomes a north-easterly, and the southerly a south-easterly motion. Similarly the undercurrents towards the equator find themselves *left behind* when they arrive in the parts of the world which have a greater velocity than their own, and from southerly and northerly they are converted into south-westerly and north-westerly currents.

The direction of currents is also greatly modified by the shape

and position of the continents, islands, shoals, sandbanks, and other obstacles which they meet in their course.

The following are the principal currents in the ocean :—

(1) **The Equatorial Current.** This vast current takes its rise in the Antarctic Ocean, and flows north-east across the Pacific Ocean till it reaches the western coast of America at about 45° south latitude It here divides into two branches, of which the smaller follows the coast of America southward, and flows round Cape Horn into the Atlantic Ocean, forming the **Cape Horn Current.** The main current flows north along the coast of Chili and Peru till it reaches the equator, when it bends westward, and traverses the Pacific Ocean from east to west. On reaching the East India Islands, it throws off a branch called the **Japan Current,** which flows north-east along the coast of Asia till it joins the current flowing through Behring's Straits into the Arctic Ocean. The other branch is much broken in its passage among the East India Islands till it reaches the Indian Ocean, when it joins the great body of water flowing from east to west till it arrives at the coast of Africa. The main stream flows north of Madagascar, turns south through the Mozambique Channel, doubles the Cape of Good Hope, and crosses the Atlantic Ocean in a north-west direction. On reaching the coast of Brazil near Cape St. Roque, it divides into two streams, of which the smaller turns southward, and flows along the coast of South America. The larger branch pursues its course along the coast of Brazil, enters the Caribbean Sea, and, following the windings of the coast, flows round the Gulf of Mexico, and issues from thence under the name of the Gulf Stream.

(2) **The Gulf Stream.** This famous current is, as already observed, connected with the Great Equatorial Current, which flows round the globe, and it receives its name from the fact that it issues from the Gulf of Mexico. The water flowing through the Caribbean Sea into the Gulf of Mexico is driven through the Straits of Florida with great force, and with a velocity of about five miles an hour. The Gulf Stream flows to the north along the east coast of Florida till it reaches the latitude of 30° N., when it

turns to the north-east at some distance from the coast of Georgia and Carolina. As it proceeds it is met by a cold polar current from the north, which flows beneath and between it and the land. It continues its course, bending further to the east when it arrives at Cape Hatteras, increasing in breadth, but decreasing in temperature and velocity. On arriving at the great Bank of Newfoundland, it bends to the east, south-east, and south, crossing the Atlantic in a broad stream till it arrives at the Azores, when it loses itself in the waters of the Atlantic. Its velocity gradually diminishes till, in the neighbourhood of the Azores, it is only about ten miles a day. The temperature of its water is considerably higher than that of the surrounding ocean. Near Newfoundland, for example, the difference of temperature is about 8°. Its breadth increases as it proceeds on its course to the north-east. Off Charleston Harbour it is about 62 miles in breadth ; near Cape Hatteras about 75 miles. Its effects, in causing an increase of temperature, are said to be felt as far as the coasts of France and Spain, and even in the British Islands.

Vessels crossing the Atlantic from Europe endeavour to avoid it by sailing further north. On the return voyage the Gulf Stream assists the navigator.

The general effect of this interchange of water between the polar regions and the tropics is the moderating of the severe cold in the former and of the great heat in the latter. The current from the Antarctic Ocean, for example, tempers the heat of Chili and Peru, while the warm waters of the Gulf Stream mitigate the severity of the northern climates.

Currents have sometimes been divided into classes, as follows :—

Constant Currents, or those whose course is regular and permanent. These are caused by the combined action of the winds, differences of temperature, the rotation of the earth, and other influences. The great currents described above are examples of this class.

Periodical Currents, or those which only flow at particular

seasons of the year, or during certain hours in the day. They are caused by the action of the tides and of the monsoons and other periodical winds.

Variable Currents, or those which change the direction of their course from time to time. These are caused by the action of the tides or of variable winds, and by the melting of the ice in the polar regions.

Counter Currents, or those which run in an opposite direction to other currents. The polar current, which we have already mentioned in connection with the Gulf Stream, is an example.

Drift Currents, or those which consist of a movement of the surface of the water in obedience to the force of the wind. The direction of the movement of the surface water borne by a drift current is sometimes different from, or even contrary to, that of the current beneath.

CURRENTS OF THE ATLANTIC OCEAN.

(1) **The Equatorial Current.**
(2) **The Gulf Stream.**
(*See* General Description of Currents.)

(3) **The Guiana Current**, connecting the Equatorial Current with the Gulf Stream. It is a continuation of the Equatorial Current through the Caribbean Sea and the Gulf of Mexico, as already explained.

(4) **The Brazil Current**, which detaches itself from the Equatorial Current off Cape St. Roque, and flows along the coast of South America towards Cape Horn. (*See* General Description of Currents.)

(5) **The Guinea Current**, a branch of the Gulf Stream, which separates itself from the latter near the Azores, and flows south-east round the coast of Africa into the Gulf of Guinea.

(6) **Rennell's Current**, probably connected with the extreme northern portion of the Gulf Stream. It flows to the south-east across the Atlantic opposite to the openings of the Irish Sea and English Channel, passes round the coasts of France and Spain in the Bay of Biscay, and after proceeding on its course some

distance to the west bends to the south-east, and falls into its original current. The portion which flows in the Bay of Biscay thus forms a kind of circle.

(7) **The Arctic Current**, flowing from the north polar regions along the coast of Greenland, across the openings of Baffin's Bay and Hudson's Bay, round the island of Newfoundland, and then between the Gulf Stream and the coast of North America. (*See* Gulf Stream.) During part of its course it is called the **Hudson's Bay Current.**

CURRENTS OF THE PACIFIC OCEAN.

(1) **The Equatorial Current.**
(2) **The Cape Horn Current.**
(3) **The Japan Current.**
(*See* General Description of Currents.)

(4) **The Mexican Current**, flowing south-east near the west coast of Mexico. This is probably a similar current to that flowing between the Gulf Stream and the east coast of North America.

CURRENTS OF THE INDIAN OCEAN.

(1) **The Equatorial Current.**
(2) **The Mozambique Current.**
(*See* General Description of Currents.)

(3) **Lagullas Current**, flowing round the Cape of Good Hope from the Indian to the Atlantic Ocean, being a continuation of the Mozambique Current.

(4) **The Madagascar Current**, flowing from north to south on the east side of the island of Madagascar, being the eastern branch of the Equatorial Current. (*See* General Description of Currents.)

(2) WINDS.

Winds are currents of air. They are created and regulated chiefly by the same causes as the currents of the ocean: the influence of temperature and the rotation of the earth on its axis. Winds are of three kinds:—

(1) **Constant**, those which blow regularly in the same direction, as the trade winds.

(2) **Periodical**, those which blow in different directions at different times of the year, according to fixed laws, as the monsoons.

(3) **Variable**, those which blow in an irregular and uncertain manner, as the sirocco.

The **velocity** of the wind varies to a very great extent. When it moves at the rate of 6 or 7 miles an hour, it is called a **gentle breeze**; at 14 or 15 miles an hour, a **stiff breeze**; at 40 miles an hour, a **high wind**, or **gale**; at from 50 to 60 miles an hour, a **storm**; at from 80 to 100 miles an hour, a **tempest**, or **hurricane.**

The **force** of the wind depends of course on its velocity. In a great storm the strength of the wind is enormous. A terrible example of the immense force of the wind was afforded by the destruction of the Tay Bridge, at Christmas, 1879, when more than seventy unfortunate railway passengers perished in the storm which blew that structure into the Firth. It is calculated that a velocity of 10 miles an hour causes a pressure of half a pound on each square foot of surface; a velocity of 20 miles, two pounds; of 30 miles, three and a half pounds; of 40 miles, nearly eight pounds; of 50 miles, more than twelve pounds; of 80 miles, nearly thirty-two pounds; and of 100 miles, nearly fifty pounds.

The air near the equator being more heated than near the poles, it expands, becomes lighter than the colder air, and ascends. Hence, the equilibrium being destroyed, as in the case of the waters of the ocean, the cold air from the north and south rushes in and displaces the warmer air. Hence we have a north wind and a south wind from the poles both setting in towards the equator. But since the rotatory motion of the earth from west to east is slower near the poles than near the equator, and the air by which it is surrounded partakes of its motion, the slower air from the poles is left behind as it arrives nearer to the equator, and therefore the north and south winds become north-east and south-east winds respectively. Since the causes which produce these movements are continual in their operation, the winds thus created are constant They are called the **Trade Winds**, on account of the great advantages which navigators derive from the regularity of their course.

North of the equator the trade winds blow from the north-east; south of the equator they blow from the south-east. They extend to about 30° on each side of the equator. Between the trade winds, and nearly coincident with the equator, but rather to the north of it, is a narrow belt in which the two trade winds meet and neutralize each other. This part of the world is called the **Region of Equatorial Calms**, or **Variables**; by sailors it is termed the **Doldrums.** In this belt, which extends to a breadth of three or four hundred miles, rain, thunder-storms, long calms, and variable winds are frequent.

The trade winds blow with great regularity in the Atlantic Ocean. In the Pacific Ocean they are less regular, on account of the numerous islands, which create land and sea breezes, and thus interfere with the steady course of the trade winds. In the Indian Ocean the south-east trade wind is regular, but the north-east trade wind is interrupted by the great mass of land north of the equator.

Above the trade winds are the currents of warm air which have been replaced by the cooler air from the northern and southern regions, and which now make their way towards the poles. Becoming colder in the higher parts of the atmosphere, they at length become of a lower temperature than the air beneath them. Hence they descend to the surface of the earth at about 30° north and south of the equator, and since their motion from west to east acquired near the equator is greater than that of the regions to which they have arrived, their directions are towards the north-east and south-east; *i.e.*, they are south-west and north-west winds. Hence in the portions of the earth north and south of the trade winds, or north of the Tropic of Cancer and south of the Tropic of Capricorn, the prevailing winds are from the south-west and north-west. These winds are sometimes called the **Return Trade Winds.**

Near the tropics, on both sides of the equator, where the

opposite currents thus cross each other, two belts of calms and variable winds occur. These are called the **Calms of Cancer** and the **Calms of Capricorn.**

Monsoons, or periodical winds, prevail chiefly in the Indian Ocean. When the sun is north of the equator, the continent of Asia becomes greatly heated, and a current of air sets in from the south-west, for reasons already explained. When the sun crosses to the south of the equator, the continent of Asia loses a large portion of its heat, and the wind then blows from the north-east to the equator, according to the principle of the trade winds. Hence from April to October the **South-west Monsoon** prevails in the Indian Ocean, and is succeeded by the **North-east Monsoon**, which blows from October to April. These periods nearly coincide with the presence of the sun north or south of the equator, not exactly however, because the influence of the sun is not felt at once to its fullest extent. The change of the monsoons is a period of strife between the two opposite air currents, and is generally accompanied by fierce storms and hurricanes.

Monsoons also occur in the Gulf of Guinea, owing to the heating of the continent of Africa, and in other parts of the world where great masses of land are exposed to the intense heat of the sun.

Land and Sea Breezes are caused by the greater heat of the land during the day and of the sea during the night. Land receives heat and gives it out more readily than water. Hence during the heat of the day an island, for example, becomes warmer than the surrounding ocean, the air above is thus rarefied, and a wind sets in from the sea. For a similar reason, the wind blows in the opposite direction, from the land towards the sea, during the night.

Various names have been given to certain winds which prevail in different parts of the world.

The **Simoom** blows over the African and Arabian deserts, and is caused by the burning heat of those regions.

The **Harmattan** is a dry wind which originates in the Sahara and blows towards the Atlantic Ocean, chiefly during the months of December, January, and February.

The **Sirocco** originates in the same region, and blows over the Mediterranean Sea, raising the temperature in the southern countries of Europe, especially in Sicily and Italy, in Spain (where it is called the **Solano**), and in Turkey (where it is called the **Samiel**).

Etesian Winds are periodical winds which blow over the Mediterranean Sea. They are somewhat similar in origin and operation to the monsoons of the Indian Ocean.

Cyclones are hurricanes which blow in a circular direction near the West Indies and in the Indian Ocean. They are often extremely violent, and cause immense damage to life and property.

Typhoons are hurricanes of a similar kind which occur in the Chinese Sea.

The **Pamperos** are south-west winds which blow over the Pampas of South America towards the Atlantic Ocean.

Tornadoes, or **Whirlwinds**, are violent tempests which occur in the West Indies, the West Coast of Africa, and the Indian Ocean generally, at the time of the changes of the monsoons.

Some of these names are employed in a general sense to denote any furious storms, especially of a sudden and destructive character.

TIDES.

Tides are the movements of the waters of the ocean when they rise and fall at nearly regular intervals, advance upon the land and up the mouths of the rivers, and then retire to a lower level. The rising of the water is called the **Flow**, its retirement the **Ebb**, of the tide. There are two flows and two ebbs of the tide in 24 hours 50 minutes and 28 seconds, so that each flow and each ebb occupies nearly six hours and a quarter. When the flow reaches its maximum height, it is said to be **high water**; when the ebb arrives at its minimum elevation, it is said to be **low water**.

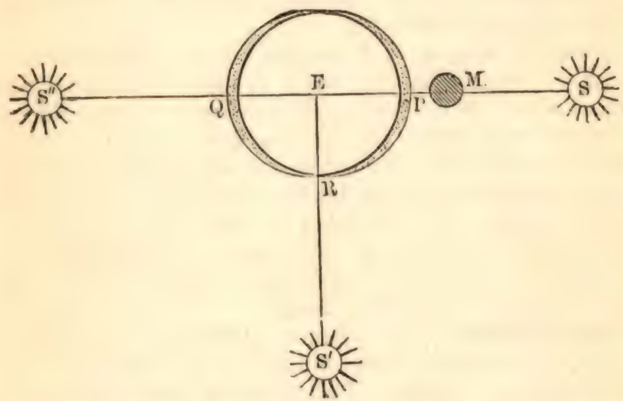
Causes. The tides are caused by the attraction of the waters of the ocean by the Sun and Moon. Though the Sun is much larger than the Moon, the latter has a greater attractive force on the waters of the Earth, because its distance is vastly less. Hence the influence of the Moon in the formation of the tides is much more powerful than that of the Sun. The period of 24 hours 50 minutes and 28 seconds is the length of time which any given spot on the Earth's surface, carried by its diurnal revolution, takes to come back to the same relative position with regard to the Moon as it occupied at the commencement of the period.

The attraction of the Sun and Moon is of course exerted on the whole mass of the Earth; but since the water has a smaller cohesive power than the land, it yields more readily to the force applied to it, and is heaped up on that side of the globe which is turned towards the attracting bodies.

In the accompanying diagram let E represent the Earth, S the Sun, and M the Moon. The waters of the globe are drawn towards P by the joint attraction of the Sun and Moon acting in the same direction along the line E S. In this position, where the Sun and Moon are both on the same side of the Earth, their

attractions exert their maximum influence on the waters of the Earth, because they act in the same direction.

The student will readily see that the water is now raised at P, but he will not so easily comprehend the fact we now mention; namely, that *at the same time* there is also high water at Q, on the opposite side of the world. The explanation is this; the water at P is raised by its being drawn away from the Earth, whilst the water at Q is raised by the Earth being drawn away from *it*. The Earth is attracted most at P, less at the centre E, and less still at Q. Hence the water at Q is, as it were, left



behind by the other parts of the globe, and is heaped up on that side at the same moment that it is elevated on the other side, nearest to the Sun and Moon. Thus each of the two bodies, the Sun and the Moon, tends to produce a flow of the tide both on the side nearest to itself and also on the opposite side at the same moment.

The highest tides will therefore occur when the Sun and Moon are on the same side of the Earth, as at S and M, or on opposite sides of the Earth, as at S" and M. The former position occurs at the time of New Moon, when the Sun and Moon are said to

be **in conjunction**; the latter position occurs at the time of Full Moon, when the Sun and Moon are said to be **in opposition.** These highest tides are called **Spring Tides**; they happen twice during each lunar period. The spring tides do not, however, occur *exactly* at the times of New and Full Moon, but about a day and a half afterwards, since the waters require some time to obey fully the forces applied to them.

It will be evident that when the flow of the tide rises highest at high water the ebb will fall lowest at low water, since an accumulation of water in one portion of the globe must be counterbalanced by a corresponding depression in that from which the water is withdrawn.

When the Moon is at M and the Sun at S′, their attractive forces act along the lines M E and S′ E, which are at right angles to each other. In this position the two forces in some degree counteract each other; but the attraction of the Moon being much greater than that of the Sun, the waters obey the impulse given to them by the former, but to a diminished degree. The position referred to occurs when the Moon is in her first and third quarters (at the time of *Half-Moon*), or in **quadrature**, as it is termed. The tides which happen at these times are the lowest; they are called **Neap Tides.**

The Tidal Wave. The movement of the waters of the ocean to obey the attractive forces of the Sun and Moon is called the tidal wave. It varies in force, direction, and velocity in different parts of the world on account of the obstacles offered to its progress by the masses of land it meets with in its passage. In the open ocean it moves rapidly and in a regular course, but in narrow and shallow seas its flow is slow and interrupted. On the other hand, for obvious reasons, the tide rises highest where its progress is most impeded, and the water is consequently more confined. It rushes with great force through narrow straits and up the gradually narrowing and funnel-shaped mouths of rivers; and it is in situations of this kind that it attains its greatest height. In the River Severn, for instance, the tide sometimes rises to a height of forty or fifty feet. In the

Bay of Fundy, in North America, a height of more than 100 feet has been registered, while in the open waters of the Pacific the difference between high and low water is often not more than two or three feet. Sometimes the tide rushes up in a great wave which can be seen for miles before it arrives. This is called the **Bore.** At the mouth of the Brahmapootra, for example, the bore attains the height of about twelve feet. This phenomenon is also observed in the Hooghly, a branch of the Ganges, in the Bay of Fundy, in the mouth of the Severn, and other places.

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List of Pictures on application.